# HABITAT SUITABILITY FOR SELECTED ADULT FISHES IN PRAIRIE STREAMS

By

WILLIAM GEORGE LAYHER

Bachelor of Science in Education
Emporia State University
Emporia, Kansas
1972

Master of Science in Environmental Biology
Emporia State University
Emporia, Kansas
1976

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
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IN PRAIRIE STREAMS

Thesis Approved:

O. Eugene Maughan
Thesis Adviser

S. L. Burks

Rudolph J. Miller

[illegible]

Anthony A. Echelle

Norman N. Durham
Dean of the Graduate College

## PREFACE

The purpose of this study was to investigate relations between eight species of warmwater fishes and their abiotic environment. This research was funded by the United States Fish and Wildlife Service, Office of Biological Services, in an effort to obtain information related to the Habitat Evaluation Procedures (HEP) program.

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# CHAPTER I

## INTRODUCTION

Increasing scarcity of water resources has resulted in conflicts among those who advocate resource development and those who advocate habitat protection (Project Evaluation Team 1979). At a national level both possibilities are considered. Legislative mandates (Fish and Wildlife Coordination Act, National Environmental Policy Act, Endangered Species Act, and The Clean Water Act) at all levels of government require consideration of habitat protection (United States Fish and Wildlife Service 1979) along with economic development. In order to protect habitats one must accurately assess the impacts of development on aquatic communities. Often, the public assumes that accurate assessment of impact is within the capabilities of current knowledge. However, many conflicting and untested methods are being used to assess such impacts (Nelson and Weaver 1981; Wood 1982; Wehnes 1982). This diversity of methods sometimes results in recommendations for mitigation that are conflicting and occasionally less than credible (Lockard 1979). These difficulties have led to recent attempts to standardize methods for impact assessment. Some standardization has been implemented but many of these methods have not been adequately tested. Use of untested methodology could result in even further loss of credibility should they prove to be unreliable (Hirsh 1978; Orth 1980; Layher and Maughan 1981).

Most methods currently used to predict impact of development on aquatic systems attempt to relate fish biomass or occurrence with physical stream parameters. The basic assumption is that once these relationships are known, they can be used to predict changes in fish distribution, occurrence, or biomass that may accompany changes in physical habitat. Inherent in this basic assumption are the ideas: 1) fish populations are responsive (e.g. closely track environments) to physical and chemical characteristics in streams; 2) fish populations are at carrying capacity; 3) relationships between fish occurrence or biomass and physical factors can be evaluated; and 4) changes in physical or chemical attributes of a stream due to man-induced impacts can be predicted.

Understanding relationships between physical environmental factors and biomass or occurrence of fishes is not a simple endeavor. Much of the available data does not relate fish species numbers or biomass to physical or chemical attributes of the aquatic environment (e.g. Winger 1981; Hulen and Angino 1979). Also, most descriptions of fish habitat are based on qualitative rather than quantitative measures (e.g. Pflieger 1975; Cross 1967; Miller and Robison 1973). For example, such terms as clear, fast, turbid, cool, deep, and shallow assume various meanings in different localities.

However, a limited amount of data quantitatively relates occurrence or biomass of species to physical stream characteristics. For example, 1) Binns and Eiserman (1979) explained 96 percent of the variation in trout standing crops in Wyoming streams with nine habitat variables, 2) Lessenden (1976) was able to relate presence and absence of fish species in several Kansas streams with three physical and chemical stream variables and 3) Chapman and Knudsen (1980) demonstrated that factors associated with habitat alteration were directly correlated with salmonid biomass in western Washington streams. There are even data which seem to indicate these relationships hold true over large areas. For example, Blair (1959) stated that darter distributions in northeastern Oklahoma follow the biotic districts described by Blair and Hubbell (1938) and Smith and Fisher (1970) showed that fish distributions in Kansas were related to climate (Cross 1970). Non-fish species such as phytoplankton (Samuels et al. 1979) and bivalve molluscs (Green 1971) also seem to follow these trends.

Based on the above considerations the United States Fish and Wildlife Service (USFWS) developed two methods for evaluating habitat changes and their impact on fisheries resources. The Instream Flow Group incremental method was developed to predict the effect of flow changes on fishes. This method has received widespread acceptance and use. The method originally required suitability or preference curve information developed by frequency of occurrence of fishes at different intervals on only three habitat variables, depth, velocity, and substrate (Waters 1976; Orth 1980; Bain et al. 1982). These curves were based on microhabitat measurements where individual fish were collected (Bovee and Cochnauer 1977). Milhous et al. (1981) later added a temperature curve for use with this model.

Reliance on so few factors for curve development led some workers to contend that these variables are adequate to predict impacts related to flow only in very simple environments and that more complex habitats require more comprehensive models (Patten et al. 1979; Orth 1980; Fritz 1980). However, such models have yet to be developed.

Currently the USFWS is attempting to develop a second more generalized habitat evaluation model (the Habitat Evaluation Procedures, HEP). This model has the capacity to incorporate data on the relationship between standing crop and a large number of habitat variables. The formal objectives of the USFWS "Aquatic Habitat Evaluation Procedures" (Raleigh 1978) are to: 1) develop objective methods to quantitatively assess baseline habitat conditions for fisheries resources; 2) provide a uniform system for predicting man-induced impacts on fisheries resources; 3) display and compare the beneficial and adverse impacts of project alternatives on fisheries resources; 4) provide a basis for recommending project modifications to compensate for or mitigate adverse effects on fisheries resources; and 5) provide data to decision makers and the public from which sound resource decisions can be made. HEP procedures, like those in the incremental procedure, are based on suitability curves. However, the manner in which curves are developed and the procedures used to obtain data for suitability curve development differ for the two methods.

Theoretically the HEP method develops curves that reflect the carrying capacity for the population under study (United States Fish and Wildlife Service 1980). The optimum value for any variable supporting or necessary to sustain a population of organisms is given a value of one. Less than optimum values for the physical or chemical variables are given values less than one. Judgements regarding which variables should be used for a given population are based on data from the literature and opinions of "species experts." Curves were developed originally from data available in the literature but more recently curves have been based on direct measurement for the population being examined. Each of the factors deemed important to the species are incorporated into a habitat suitability model (HSI) in which variables are weighted so as to reflect importance. A composite HSI is then derived for each life stage of the species for the stream reach being evaluated. This score or index can be converted to habitat units by multiplying the overall HSI by area of a stream segment or total area of available habitat (United States Fish and Wildlife Service 1980).

Different elements of this procedure seem to have variable reliability. For example Layher and Maughan (1981) found low correlations between calculated HSI values (several species of adult fishes) and fish biomass in Kansas streams, even though suitability curves for several species of adult fishes developed from Oklahoma and Kansas field data closely approximated those curves previously developed by the USFWS. Layher and Maughan (1981) developed the following hypotheses: 1) the Fish and Wildlife Service model for calculating HSI values did not correctly weight the importance of individual factors; or 2) variables for inclusion in the model were incorrectly selected; or 3) the model was theoretically flawed. The authors suggested retention of the habitat suitability curves but recommended restricting use of the HSI model to a planning level until further information was available.

Both of the previously discussed habitat evaluation models are based on concepts deeply rooted in niche theory. The aquatic resource manager generally uses the concept of the realized niche as a constrained hypervolume (Hutchinson 1957) in which environmental factors define the resource space occupied by a population, stock or species. Theoretically the physical factors in the HSI model are those factors that define the resource space of the organism. The weighting factors tend then to be a probability statement on relative importance of the limiting factors. Increased or decreased populations can be obtained by expanding or contracting one or more factors that define the realized niche of the population. If we then have selected the correct factors and weighted them all correctly, and if the interactive portion of the equation operates additively, and if populations are at carrying capacity, we should be able to predict biomass or standing crop. Pianka (1978) contends that strict adherence to this definition of niche ignores the biotic factors which may also limit the hypervolume. However the HEP procedures do not preclude relating standing crop to biotic factors. In addition, Jones and Maughan (1980) and Orth and Maughan (1980) argued that such a limitation may not be severe in some southern Great Plains streams where it appears that abiotic factors are commonly limiting.

In the preceding paragraph I dealt with conditions that must be met before the HSI model can be completely predictive. Because all these conditions are not likely to be met at every location, I have developed an alternate method for predictive purposes. This method incorporates suitability curves similar to those used in HEP and are based on biomass estimates of species at individual sites.

The objectives of this study were to: 1) determine relationships between individual abiotic factors and biomass of fish populations; 2) relate physical and chemical factors to species occurrence; and 3) assess these relationships with regard to habitat quality.

The relationship between environmental variables and adult populations of the following eight species of fishes were investigated: largemouth bass, *Micropterus salmoides*; spotted bass, *M. punctulatus*;

white crappie, Poxomis annularis; channel catfish, Ictalurus punctatus; green sunfish, Lepomis cyanellus; slenderhead darter, Percina phoxocephala; orangethroat darter, Etheostoma spectabile; and central stoneroller, Campostoma anomalum.

# CHAPTER II

## DESCRIPTION OF STUDY AREA

Some of the data used in this study were obtained by the Kansas Fish and Game Commission from 1974 to 1978 (420 sample sites) throughout the sixteen major river basins in the state of Kansas (Figure 1). Each site was characterized geographically and climatologically (Layher et al. 1978) and physical and chemical stream variables were measured (Table 1). Most sample locations are associated with one of three major biotic districts in the state: short-grass prairie, mixed-grass prairie or tall-grass prairie.

In the summer of 1981 additional data was collected from 50 stream locations in the northern half of Oklahoma (Figure 2). These sites were characterized by biotic districts as defined by Blair and Hubbell (1938) and physical and chemical attributes were measured (Table 2). The sample sites in Oklahoma fall within five of the 11 biotic districts of the state: short-grass plains, sand areas, mixed-grass plains, osage-savannah, and the Cherokee prairie.

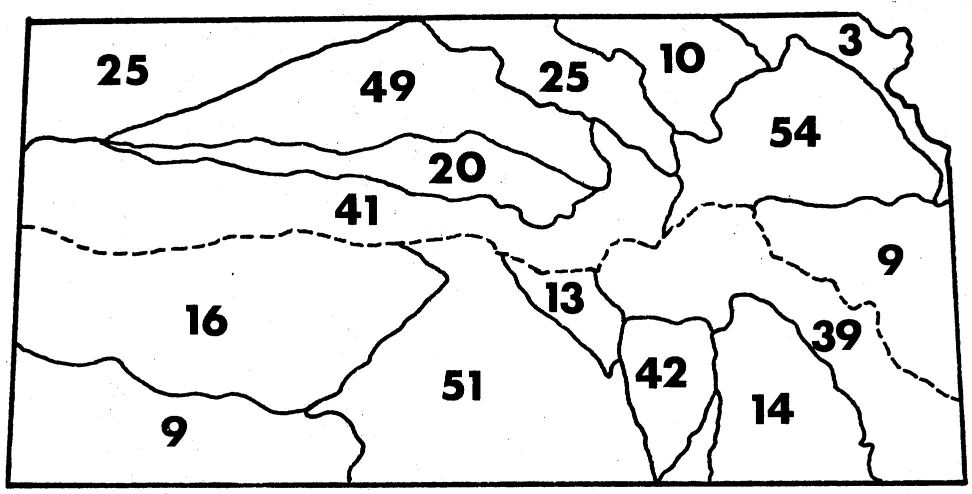


Figure 1. Locations of stream sample sites in Kansas. Numbers indicate number of stream segments sampled within the outlined river basins. All river basins outlined above the dotted line eventually drain into the Missouri River while those below the dotted line flow into the Arkansas River.

Table 1. Chemical and physical characteristics of 420 stream sample sites in Kansas. Data taken from the Kansas Fish and Game Commission stream survey.

| Variable | N | Mean | Standard deviation | Minimum value | Maximum value | Standard error of the mean | Variance |
|---|---|---|---|---|---|---|---|
| Calcium hardness (ppm) | 373 | 252.64 | 158.52 | 0.0 | 1350.0 | 8.2079 | 25129.3206 |
| Chlorides (ppm) | 395 | 99.66 | 184.30 | 0.1 | 1870.0 | 9.2735 | 33969.1486 |
| Conductivity (μmhos/cm) | 218 | 1073.51 | 1047.93 | 85.0 | 9100.0 | 70.9750 | 1908164.9144 |
| Dissolved oxygen (ppm) | 380 | 9.99 | 3.31 | 1.0 | 19.0 | 0.1700 | 10.9822 |
| Gradient (m/km) | 369 | 1.46 | 1.11 | 0.1 | 7.9 | 0.0578 | 1.2340 |
| Growing season (days) | 420 | 178.62 | 11.69 | 82.0 | 194.0 | 0.5708 | 136.8563 |
| Magnesium hardness (ppm) | 371 | 92.71 | 164.18 | 0.0 | 2530.0 | 8.5240 | 26956.3949 |
| Maximum width (m) | 405 | 11.99 | 12.21 | 0.9 | 125.5 | 0.6069 | 149.2012 |
| Mean depth (m) | 420 | 0.49 | 0.39 | 0.1 | 4.5 | 0.0193 | 0.1547 |
| Mean width (m) | 420 | 9.51 | 10.72 | 0.9 | 110.0 | 0.5235 | 115.1208 |
| Minimum width (m) | 406 | 6.39 | 8.59 | 0.3 | 101.1 | 0.4263 | 73.8064 |
| Nitrates (ppm) | 384 | 7.47 | 7.40 | 0.0 | 92.4 | 0.3778 | 54.8227 |
| pH | 401 | 8.01 | 0.60 | 3.5 | 9.3 | 0.0300 | 0.3631 |

Table 1. Continued.

| Variable | N | Mean | Standard deviation | Minimum value | Maximum value | Standard error of the mean | Variance |
|---|---|---|---|---|---|---|---|
| Phosphates (ppm) (Ortho) | 396 | 0.60 | 0.92 | 0.0 | 9.0 | 0.0466 | 0.8608 |
| Pool (%) | 409 | 42.66 | 40.24 | 0.0 | 100.0 | 1.9898 | 1619.4160 |
| Riffle (%) | 408 | 9.41 | 16.19 | 0.0 | 100.0 | 0.8015 | 262.1654 |
| Run (%) | 408 | 48.41 | 42.40 | 0.0 | 100.0 | 2.0991 | 1797.8804 |
| Runoff (in/yr) | 420 | 2.02 | 1.99 | 0.1 | 10.0 | 0.0972 | 3.9682 |
| Sulfates (ppm) | 380 | 146.12 | 159.95 | 0.0 | 1250.0 | 8.2055 | 25586.0136 |
| Total alkalinity (ppm) | 403 | 217.28 | 73.55 | 0.0 | 590.0 | 3.6642 | 5411.0711 |
| Total dissolved solids (ppm) | 210 | 498.88 | 527.30 | 22.0 | 4200.0 | 36.3872 | 278016.1149 |
| Total length (m) | 416 | 74.13 | 173.37 | 6.0 | 2414.0 | 8.5004 | 30059.0561 |
| Turbidity (JTU) | 253 | 41.54 | 75.72 | 0.0 | 560.0 | 4.7608 | 5734.3596 |
| Velocity (m/sec) | 377 | 0.19 | 0.41 | 0.0 | 5.7 | 0.0215 | 0.1755 |
| Volume of flow ($m^3$/sec) | 377 | 0.90 | 3.21 | 0.0 | 28.3 | 0.1656 | 10.3411 |
| Water temperature (C) | 405 | 20.86 | 7.07 | 1.0 | 36.0 | 0.3514 | 50.0168 |

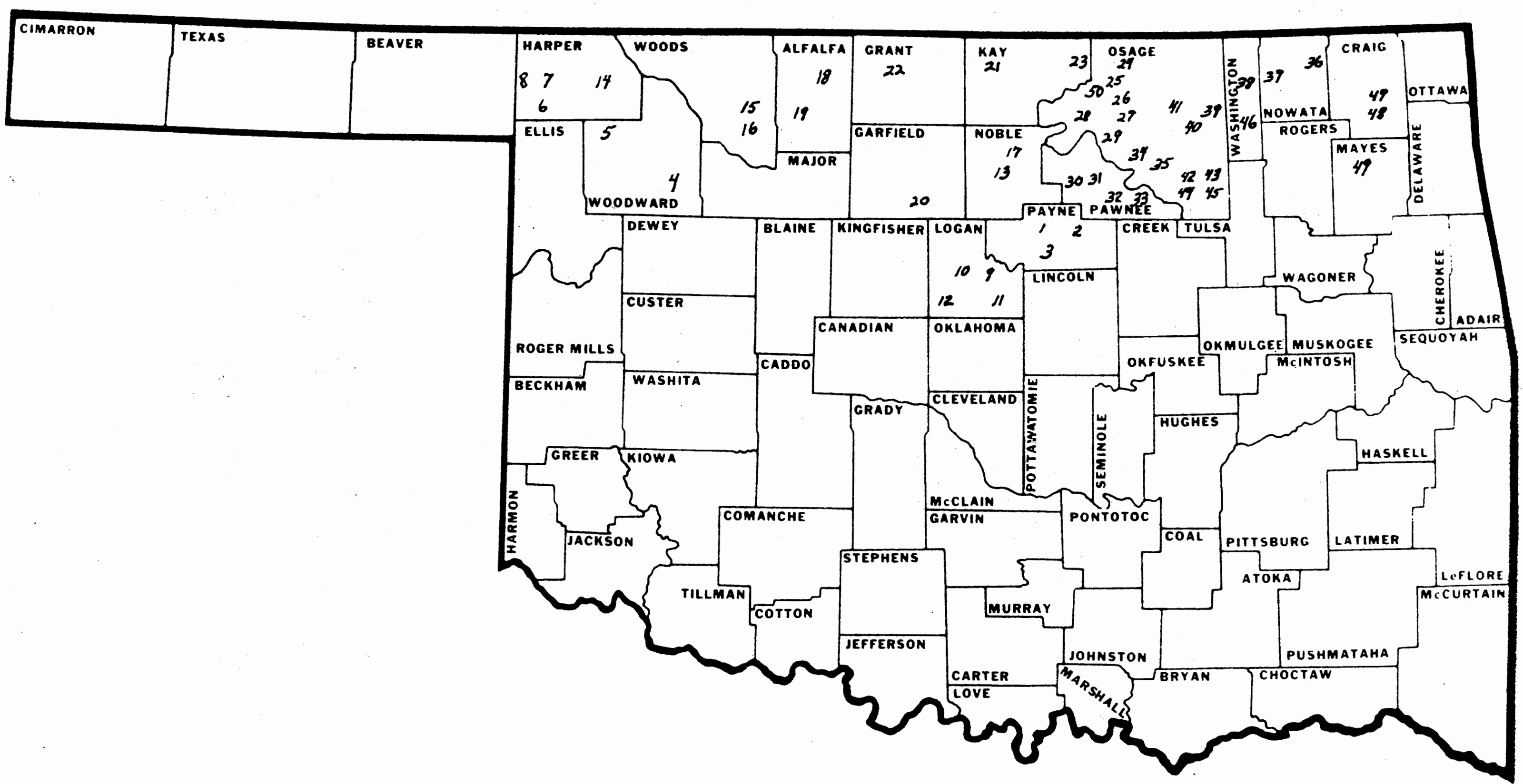


Figure 2. Locations of stream sample sites in Oklahoma. Each number represents an individual site and numbers reflect sampling sequence.

Table 2. Chemical and physical characteristics of 50 stream sites in Oklahoma.

| Variable | Mean | Standard deviation | Minimum value | Maximum value | Standard error of the mean | Variance |
|---|---|---|---|---|---|---|
| Calcium hardness (ppm) | 233.74 | 274.42 | 35.0 | 1690.0 | 38.81 | 75305.502 |
| Chlorides (ppm) | 168.06 | 179.16 | 22.5 | 1025.0 | 25.34 | 32099.456 |
| Conductivity (µmhos/cm) | 1041.22 | 1488.12 | 155.0 | 10500.0 | 210.45 | 2214496.869 |
| Dissolved oxygen (ppm) | 6.29 | 1.96 | 2.8 | 10.9 | .28 | 3.842 |
| Gradient (m/km) | 1.69 | 2.03 | 0.2 | 10.0 | .29 | 4.101 |
| Growing season (days) | 201.40 | 7.29 | 180.0 | 210.0 | 1.03 | 53.102 |
| Magnesium hardness (ppm) | 107.38 | 170.79 | 10.0 | 1060.0 | 24.15 | 29168.934 |
| Maximum width (m) | 13.35 | 6.62 | 3.0 | 33.5 | .94 | 43.800 |
| Mean depth (m) | 0.39 | 0.19 | 0.1 | 0.8 | .03 | 0.036 |
| Mean width (m) | 10.82 | 5.79 | 2.5 | 30.3 | .82 | 33.507 |
| Minimum width (m) | 8.03 | 5.17 | 1.3 | 27.5 | .73 | 27.766 |
| Nitrates (ppm) | 0.14 | 0.21 | 0.0 | 0.9 | .03 | 0.046 |
| pH | 7.97 | 0.40 | 7.1 | 9.0 | 0.06 | 0.159 |
| Phosphates (ppm) | 0.11 | 0.18 | 0.0 | 0.8 | 0.03 | 0.034 |

Table 2. Continued.

| Variable | Mean | Standard deviation | Minimum value | Maximum value | Standard error of the mean | Variance |
|---|---|---|---|---|---|---|
| Pool (%) | 65.40 | 44.36 | 0.0 | 100.0 | 6.27 | 1968.204 |
| Riffle (%) | 2.60 | 7.91 | 0.0 | 40.0 | 1.12 | 62.490 |
| Run (%) | 32.00 | 42.19 | 0.0 | 100.0 | 5.97 | 1779.592 |
| Runoff (in/yr) | 3.92 | 1.69 | 1.0 | 10.0 | 0.24 | 2.871 |
| Sulfates (ppm) | 92.78 | 134.08 | 4.0 | 580.0 | 18.96 | 17978.706 |
| Total alkalinity (ppm) | 186.18 | 102.84 | 50.0 | 740.0 | 14.54 | 10575.416 |
| Total dissolved solids (ppm) | 452.06 | 696.13 | 72.0 | 4950.0 | 98.45 | 484591.690 |
| Turbidity (JTU) | 69.00 | 57.26 | 0.0 | 270.0 | 8.10 | 3278.204 |
| Velocity (m/sec) | 0.06 | 0.09 | 0.0 | 0.4 | 0.01 | 0.008 |
| Volume of flow ($m^3$/sec) | 0.142 | 0.25 | 0.0 | 1.1 | 0.04 | 0.062 |
| Water temperature (C) | 27.11 | 2.71 | 21.1 | 33.5 | 0.38 | 7.319 |

## CHAPTER III

## MATERIALS AND METHODS

The data set used in the development of species occurrence models, habitat suitability curves and biomass models was obtained from the Kansas Fish and Game Commission (Layher et al. 1978). This report was delivered to the Kansas Department of Health and Environment pursuant to section 208 of Public Law 92-500. The data set contained 420 observations (stream locations) with measurements of 30 physical and chemical variables at each stream site as well as descriptive variables identifying data and location of each sample (Table 3). Standing crop estimates were made for all fish species at each location. These data were incorporated into a Statistical Analysis System (SAS) data set and all statistical analysis were performed utilizing the "SAS User's Guide" (Blair 1979).

The models developed herein depend on two basic assumptions: 1) habitat conditions control the occurrence or nonoccurrence of a species at a stream site (tolerance limits); 2) another set of controls which include habitat conditions, at least partly determines the standing crop or biomass of fish in a stream segment.

### Species Occurrence Models

To evaluate the conditions that control whether a species occurs at a location, I determined which variables were correlated with

Table 3. Physical-chemical, biological and descriptive variables for sites where data were taken in Kansas.

| Descriptive variables | Physical variables | Chemical variables |
|---|---|---|
| Basin (number) | Air temperature (C) | Calcium hardness (mg/l) |
| County (number) | Gradient (m/km) | Chlorides (mg/l) |
| Date | Growing season (frost-free days) | Conductivity (μmhos/cm) |
| Day | Maximum width (m) | Hydroxide alkalinity (mg/l) |
| Month | Mean depth (m) | Magnesium hardness (mg/l) |
| Sampling method | Mean width (m) | Nitrates (mg/l) |
| Segment | Minimum width (m) | pH |
| Station (number) | Pool (%) | Phosphates (mg/l) |
| Stream (number) | Riffle (%) | Sulfates (mg/l) |
| Year | Riffle depth (m) | Total alkalinity (mg/l) |
| | Run (%) | Total dissolved solids (mg/l) |
| | Secchi disc (m) | Turbidity (JTU's) |
| | Surface area (ha) | |
| | Total length of site (m) | |
| | Velocity (m/sec) | |
| | Volume of flow ($m^3$/sec) | |
| | Water temperature (C) | |

Biological variables:

1) Standing crop estimates for approximately 100 fish species;
2) Presence-absence (0 or 1) for each fish species.

presence or absence; i.e.: the limiting factors of niche theory. For each species, locations were stratified into two groups according to presence or absence of the species. The F-test was used to determine homogeneity or heterogeneity of variances of each variable measured between those sites with the species present and those with it absent. Then student t-tests were used, for each variable, to test for statistical significance between the means of the two groups. Variables which showed statistically significant differences between presence and absence groups for a given species were then used to develop a predictive model for occurrence of that species by use of a discriminant function analysis.

Locations that were misclassified under this model were identified. Variables were then created to identify the river basin, stream, sampling station and methods of collection. The sites misclassified were then plotted graphically in order to help identify the causes of misclassifications.

## Development of Habitat Suitability Curves and Biomass Models

The procedure so far outlined deals only with whether or not a species occurred at a location. Obviously, it would be useful to predict gradations of habitat suitability. One approach is to determine if a relationship exists between variation in standing crop and variation in physical or chemical variables. Plots of the standing crop of each species against physical and chemical variables were generated. When all of the data available in this study were used, the plots generated showed no pattern. For example many data points with similar habitat measurements differed considerably in standing crops of the same species. Often the plots for these data were nonlinear and would have required complex polynomial equations to describe the relationship. Conversion of this polynomial equation to a linear relationship would have prohibitively increased input data requirements.

The standing crop data collected in Kansas was obtained by eight different sampling techniques: 1)shocking (sample method 1), 2) seining (sample method 2), 3) mark and recapture using seining (sample method 3), 4) seining and shocking (sample method 4), 5) kill technique using rotenone (sample method 5), 6) mark and recapture using rotenone as the final capture technique (sample method 6), 7) mark and recapture using seining as the first collection method followed by a final capture using shocking (sample method 7), and 8) mark and recapture using only shocking (sample method 8). Separation of the data by sampling method helped in the analysis but could not completely overcome these problems (Layher and Maughan 1981).

To overcome these problems, I used the data to develop suitability curves relating standing crop of each fish species to each variable measured. The range of each variable was divided into increments and the mean standing crop values were calculated within each increment. (See Table 4 for an explanation of SAS computer procedures used.) Curves were generally drawn to pass through these means. However, if an observation yielded a high estimate of standing crop at a point where the major portion of the standing crop data showed low values, and the standing crop value was based on only a few samples, the curve was drawn according to the median value of the data.

To scale suitability to biomass, the highest mean standing crop

Table 4. SAS procedures utilized to develop a habitat suitability curve for the physical variable mean stream width (MEAN_WID) for spotted bass (SPOT_B). For other variables substitute variable code for MEAN_WID. For other species substitute new species identifier for SPOT_B.

---

STEP

A. PROC PLOT; PLOT SPOT_B *MEAN_WID;

B. MEAN_WID=INT (MEAN_WID/10)* 10; (use after a data statement.)

C. PROC MEANS; VAR SPOT_B;

D. PROC CHART; VBAR MEAN_WID/TYPE=MEAN SUMVAR=SPOT_B DISCRETE;

E. PROC SORT; BY MEAN_WID;

F. PROC MEANS; BY MEAN_WID; VAR SPOT_B

RESULTS BY STEP

A. A plot of spotted bass standing crops on the ordinate and mean width on the abscissa.

B. Has the effect or producing intervals of mean width in groups of 10 meters (0 ≤ MEAN_WID < 10; 10 ≤ MEAN_WID < 20, etc.).

C. Computes mean for spotted bass standing crop estimates with N value and other descriptive statistics.

D. Produces a bar chart of mean standing crop for each interval of mean width.

E. Sorts the data set by mean width which now has an interval value (0 for 0 ≤ MEAN_WID < 10; 10 for 10 ≤ MEAN_WID < 20, etc.).

F. Produces a table with interval values for mean width. Includes the actual mean value for spotted bass for each interval as well as the range, standard deviation, maximum and minimum values, and N.

NOTE: The bar graph in conjunction with data printed out under step F are used to develop the habitat suitability curve.

---

value represented by a large proportion of the observations was usually assigned a suitability value of one (Figure 3). Habitat suitability values were then assigned proportionally to segments of the curve passing through any given increment of a physical or chemical variable. The effect of this procedure was to linearize the f(x) = standing crop where x is one of the physical or chemical variables.

Curves were developed from the Kansas data relating most of 30 physical and chemical variables measured in the field to standing crop of each of the eight fish species. Each observation in the data set was then assigned suitability values ranging from 0 to 1 based on the habitat suitability curves for each variable for a given species. Stepwise multiple regression runs were then utilized (SAS PROC STEPWISE) to identify variables which explained the variation of standing crop by species.

From these procedures models were developed to estimate standing crop at a given location based on measurement of the physical habitat. However it must be emphasized that: 1) the regressions were performed on suitability index values and not on empirical data; 2) coefficients from resulting equations cannot be used to evaluate variable importance or relationships between variables because different scales of measure were used for each variable; 3) the model is a combined estimator of standing crop; the entire model must be used.

## Testing the Models

### Field Sampling

In order to test the validity of these models and to evaluate the relationship between abiotic factors and fish populations over a wide

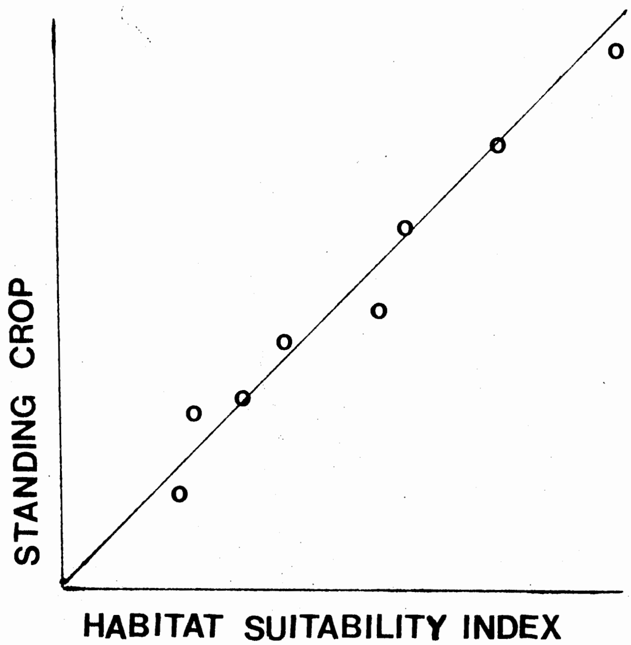


Figure 3. Theoretical result of plotting standing crop of a hypothetical species against a habitat suitability index for a single variable.

geographical area; data were collected at 50 stream sites in Oklahoma (Table 5). Initially I attempted to use complete kill techniques because preliminary analysis on the Kansas data had indicated that complete kill techniques gave more reliable results than non-kill techniques (Layher and Maughan 1981). However, cyanide was not permitted for use in Oklahoma and preliminary tests of rotenone (Marking and Bills 1976) and primacord (Layher 1981) were found to be inefficient. Consequently, population estimates at each site were made using the depletion method (Carle and Maughan 1980) and the maximum likelihood estimator (Carle and Strubb 1978). The procedures outlined by Raleigh and Short (1981) were followed in order to meet the assumptions of this sampling technique.

The field procedure for use of this technique is as follows: a 30-meter section of stream was blocked upstream and downstream with ¼-inch mesh net. In soft substrates, metal fence posts were driven through loops in the lead line to ensure blockage. In sites with hard substrates, large rocks were placed on the lead line. At each site, fishes were collected with a boat mounted DC electrofishing unit composed of a generator, variable voltage pulsator (Coffelt Model VVP-2C), and two hand held, remote electrodes. The cathode was imbedded in the boat bottom. One complete pass through the site constituted a sampling effort. The procedure was repeated until depletions of all species were made. The number of passes made through a site varied from a minimum of three to a maximum of seven. If a species was extremely abundant, each 25 mm length group was treated as a separate species when computing the number of fishes in the sampled area but recombined to obtain biomass estimates. Average weights were

Table 5. Locations, dates, and names of stream sites sampled in Oklahoma. Site numbers depict order of sampling and are used for reference.

| Site | Location | Date sampled | Stream name and county |
|---|---|---|---|
| 1 | SE¼,S10,T19N,R1E | 6-01-1981 | Stillwater Creek, Payne |
| 2 | SW¼,S23,T19N,R4E | 6-08-1981 | Council Creek, Payne |
| 3 | SW¼,S32,T18N,R2E | 6-09-1981 | Wildhorse Creek, Payne |
| 4 | NE¼,S16,T22N,R19W | 6-10-1981 | North Canadian River, Woodward |
| 5 | NE¼,S16,T24N,R22W | 6-10-1981 | Wolf Creek, Woodward |
| 6 | NW¼,S30,T25N,R25W | 6-11-1981 | Clear Creek, Harper |
| 7 | NE¼,S9,T26N,R25W | 6-11-1981 | Beaver River, Harper |
| 8 | NE¼,S15,T26N,R26W | 6-11-1981 | Kiowa Creek, Harper |
| 9 | SW¼,S10,T18N,R2W | 6-16-1981 | Beaver Creek, Logan |
| 10 | SE¼,S8,T18N,R3W | 6-18-1981 | Skeleton Creek, Logan |
| 11 | NW¼,S28,T16N,R1W | 6-18-1981 | Bear Creek, Logan |
| 12 | NE¼,S17,T15N,R3W | 6-19-1981 | Cottonwood Creek, Logan |
| 13 | SW¼,S26,T22N,R1E | 6-22-1981 | Black Bear Creek, Noble |
| 14 | NE¼,S13,T27N,R22W | 6-24-1981 | Buffalo Creek, Harper |
| 15 | SE¼,S14,T26N,R14W | 6-25-1981 | Little Eagle Chief Creek, Woods |
| 16 | SE¼,S26,T26N,R14W | 6-25-1981 | Eagle Chief Creek, Woods |
| 17 | NW¼,S14,T23N,R1E | 6-26-1981 | Red Rock Creek, Noble |
| 18 | SW¼,S18,T28N,R9W | 7-02-1981 | Sandy Creek, Alfalfa |
| 19 | NW¼,S14,T27N,R11W | 7-02-1981 | Salt Fork of the Arkansas, Alfalfa |
| 20 | NE¼,S5,T20N,R5W | 7-06-1981 | Skeleton Creek, Garfield |
| 21 | NE¼,S27,T28N,R1W | 7-07-1981 | Bitter Creek, Kay |
| 22 | SE¼,S27,T27N,R6W | 7-08-1981 | Pond Creek, Grant |
| 23 | NW¼,S31,T28N,R5E | 7-09-1981 | Little Beaver Creek, Kay |
| 24 | SE¼,S24,T28N,R6E | 7-09-1981 | Elm Creek, Osage |
| 25 | NW¼,S2,T26N,R6E | 7-13-1981 | Salt Creek, Osage |
| 26 | SW¼,S19,T23N,R7E | 7-14-1981 | Salt Creek, Osage |
| 27 | SE¼,S7,T25N,R6E | 7-16-1981 | Little Chief Creek, Osage |
| 28 | SW¼,S36,T25N,R4E | 7-16-1981 | Doga Creek, Osage |
| 29 | NW¼,S5,T23N,R6E | 7-17-1981 | Gray Horse Creek, Osage |
| 30 | NE¼,S29,T22N,R4E | 7-21-1981 | Black Bear Creek, Pawnee |
| 31 | SW¼,S33,T22N,R5E | 7-22-1981 | Black Bear Creek, Pawnee |
| 32 | NE¼,S12,T21N,R5E | 7-22-1981 | Camp Creek, Pawnee |
| 33 | SE¼,S1,T21N,R6E | 7-23-1981 | Hell Roaring Creek, Pawnee |
| 34 | NE¼,S25,T23N,R6E | 7-23-1981 | Sycamore Creek, Osage |
| 35 | SE¼,S27,T23N,R7E | 7-24-1981 | Bug Creek, Osage |
| 36 | SE¼,S26,T27N,R17E | 7-28-1981 | Big Creek, Nowata |
| 37 | SW¼,S8,T26N,R16E | 7-29-1981 | California Creek, Nowata |
| 38 | NE¼,S6,T27N,R13E | 7-24-1981 | Little Caney River, Washington |
| 39 | NE¼,S4,T23N,R12E | 8-04-1981 | Candy Creek, Osage |
| 40 | SE¼,S12,T23N,R11E | 8-04-1981 | Bird Creek, Osage |
| 41 | NW¼,S21,T24N,R10E | 8-05-1981 | Birch Creek, Osage |
| 42 | SE¼,S29,T23N,R9E | 8-06-1981 | Hominy Creek, Osage |
| 43 | SE¼,S29,T23N,R9E | 8-06-1981 | Hominy Creek, Osage |
| 44 | SE¼,S32,T22N,R10E | 8-10-1981 | Wildhorse Creek, Osage |
| 45 | SW¼,S34,T22N,R11E | 8-10-1981 | Tall Chief Creek, Osage |

Table 5. Continued.

| Site | Location | Date Sampled | Stream name and county |
|---|---|---|---|
| 46 | SW¼,S16,T25N,R13E | 8-11-1981 | Caney River, Washington |
| 47 | NE¼,S35,T24N,R20E | 8-12-1981 | Big Cabin Creek, Craig |
| 48 | SW¼,S35,T24N,R20E | 8-12-1981 | Big Cabin Creek, Craig |
| 49 | NE¼,S23,T23N,R19E | 8-13-1981 | Rock Creek, Mayes |
| 50 | SW¼,S13,T26N,R5E | 8-18-1981 | Salt Creek, Osage |

then determined for each species or group in the collection. To estimate biomass for each species at a site the difference between number of fish collected and the number estimated to be in the sample area was multiplied by the average weight of the collected specimens; the product was then added to the total biomass of collected specimens. Biomass was expressed as kg/ha.

Larger fish were measured and weighed to the nearest gram with an accuracy of ±2 grams. Smaller fish such as sunfishes were batch weighed in 25 mm length groups. Cyprinids and darters were batch weighed together, transferred to the lab, identified to species, and weighed to the nearest .1 gram. Weights recorded in the lab were converted to percent of the weight of the group and biomass of each species was determined from its percentage of the group weight as measured in the field. All fish weighed in the field were released after depletion sampling was completed.

After fish populations were sampled, the block nets were removed, and the following measurements were made at one-meter intervals along each of three transects, one at each end of the site and one midway between the locations of the block nets: depth (m) was measured with a metric wading rod; current velocity (m/s) measured with a pygmy current meter at 0.6 of the depth from the water surface; and substrate classified and coded according to a modified Wentworth scale (Bovee and Cochnauer 1977). Average depth and velocity were estimated as the mean of all transect measurements. Each substrate category was recorded as percent of total observations. The percents of the sample site comprised of pool, riffle, and run habitats were estimated as follows: pool = percent of current readings at 0 cm/s, riffle = estimated percent of the site with projecting substrate above the water surface or with turbulent flow, run = percent of the current readings greater than 0 cm/s but with no apparent turbulence. Maximum and minimum stream widths (m) within the sampling area were also determined.

Hach, EPA approved, meters were used at each site to measure water temperature (C), conductivity (µmhos/cm), total dissolved solids (mg/l), dissolved oxygen (mg/l), and pH in the field. Water samples for laboratory analysis were taken in acid washed polypropylene bottles, acidified to pH of 2, and transported on ice. After raising the pH to about 7, soluble reactive phosphorus (SRP) and nitrate ($NO_3^-$-N) were measured as described by Strickland and Parsons (1968) (EPA standard reference solutions were used to validate the methods each time samples were processed). Chlorides, sulfates, total hardness, calcium hardness, magnesium hardness, total alkalinity, and turbidity were all determined with a Hach DR-EL/2 Direct Reading Engineers Laboratory Kit. Boyd (1976, 1977, 1980) has found that the reliability of such units are adequate for general surveys of water quality, fisheries management decisions, and research requiring approximate estimates of water quality.

Gradients (m/km) for each site were determined from U.S. Geological Survey (1969) topographic maps. Growing season (frost-free days) was determined from maps given by Hambridge and Drown (1941). Runoff (in/yr) values were also obtained from climatological maps (Oklahoma State University 1979).

## Species Occurrence

A calibration data set was made using the SAS PROC DISCRIM procedures from the Kansas stream survey data for each of eight species of fish. This data set was then used to classify each stream site in Oklahoma, according to probability of occurrence of a fish species, to determine whether fish samples at each site fit the discriminant analysis model based on Kansas physical and chemical stream variable measurements. A discriminant analysis was also performed for each species based only on Oklahoma data.

Species Biomass Predictions

Equations based on Kansas data were also used to predict biomass for each species at the Oklahoma sample sites. A separate regression equation to predict standing crops was developed for each species for each of the eight sampling methods used to collect biomass data in Kansas (Appendix K). Pearson and Spearman correlation coefficients were then calculated between observed and predicted biomass for each species.

The habitat suitability curves developed from the Kansas stream survey data were used to assign index values for each variable measured at sites sampled in Oklahoma. Predictive equations were then developed for the Oklahoma data to determine whether these curves would explain variation in standing crops in Oklahoma streams. This approach allowed a determination of whether there was any indication that the same variables were correlated with fish populations in Oklahoma and Kansas streams.

# CHAPTER IV

# RESULTS-SPOTTED BASS

## Species Occurrence Model

Data on all variables used in the discriminant function analysis (Table 6) were not taken at each sampling location in Kansas. However, the 109 sites where complete observations were taken represent 11 of the 16 major river basins found in Kansas (Table 7). The following variables are listed in order from greatest to least importance in discriminating between presence and absence of spotted bass: water temperature, mean depth, turbidity, pH, dissolved oxygen, percent pool, percent run, total dissolved solids, chlorides, maximum stream width, conductivity, and phosphates.

Discriminant analysis misclassified only 2 (4.6 percent) of the 43 sites that contained spotted bass but misclassified 19 sites of non-occurrence. Nine of the latter group of sites were outside the natural range of spotted bass (Cross 1967) and eight of these nine locations were in the Kansas River Basin.

Recently established populations of spotted bass have been reported at some stream locations within the Kansas River Basin (Layher et al. 1978). These populations indicate that, as indicated by the discriminant model, the basin provides the necessary requirements for spotted bass. The remaining site where the model incorrectly predicted spotted bass occurrence appears to represent an isolated area of suit-

Table 6. Significant relationships between presence and absence groups of spotted bass (P = presence, A = absence) and physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Chlorides (mg/l) | A | 335 | 107.85 | 194.98 | 0.1 | 1870.0 | | | | |
| | P | 60 | 53.98 | 95.58 | 0.5 | 700.0 | U[2] | 3.3048 | 163.7 | 0.0012 |
| Conductivity | A | 161 | 1193.09 | 1123.26 | 85.0 | 9100.0 | | | | |
| (μmhos/cm) | P | 57 | 735.79 | 702.39 | 200.0 | 4000.0 | U | 3.5610 | 158.0 | 0.0005 |
| Dissolved oxygen | A | 316 | 10.22 | 3.30 | 1.0 | 19.0 | | | | |
| (mg/l) | P | 64 | 8.91 | 3.21 | 4.0 | 19.0 | U | 2.9437 | 91.9 | 0.0041 |
| Maximum width (m) | A | 342 | 11.13 | 12.59 | 0.9 | 125.5 | | | | |
| | P | 63 | 16.63 | 8.59 | 6.0 | 45.4 | U | -4.2929 | 117.5 | 0.0001 |
| Mean depth (m) | A | 351 | 0.47 | 0.37 | 0.1 | 4.5 | | | | |
| | P | 69 | 0.65 | 0.46 | 0.1 | 3.1 | U | -3.0543 | 86.2 | 0.0030 |
| Mean width (m) | A | 351 | 8.70 | 11.00 | 0.9 | 110.0 | | | | |
| | P | 69 | 13.68 | 8.08 | 3.0 | 45.7 | U | -4.3854 | 123.4 | 0.0001 |
| Minimum width (m) | A | 342 | 6.11 | 9.11 | 0.3 | 101.2 | | | | |
| | P | 64 | 7.90 | 4.79 | 0.6 | 19.8 | U | -2.3057 | 163.3 | 0.0224 |
| Phosphates (mg/l) | A | 337 | 0.64 | 0.96 | 0.0 | 9.0 | | | | |
| | P | 59 | 0.37 | 0.61 | 0.0 | 3.4 | U | 2.8319 | 116.1 | 0.0055 |
| Pool (%) | A | 342 | 40.66 | 40.24 | 0.0 | 100.0 | | | | |
| | P | 67 | 52.88 | 38.94 | 0.0 | 100.0 | E[3] | -2.2851 | 417.0 | 0.0228 |

Table 6. Continued.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Run (%) | A | 341 | 50.37 | 47.38 | 0.0 | 100.0 | | | | |
| | P | 67 | 35.55 | 40.40 | 0.0 | 100.0 | E | 2.7386 | 406.0 | 0.0064 |
| Sulfates (mg/l) | A | 322 | 153.12 | 154.43 | 0.0 | 1250.0 | | | | |
| | P | 58 | 107.26 | 184.41 | 1.0 | 95.0 | E | 2.1083 | 378.0 | 0.0445 |
| Total dissolved solids (mg/l) | A | 154 | 564.84 | 573.32 | 22.0 | 4200.0 | | | | |
| | P | 56 | 317.48 | 310.64 | 125.0 | 1750.0 | U | 3.9826 | 177.7 | 0.0001 |
| Turbidity (JTU's) | A | 200 | 45.62 | 84.07 | 0.0 | 560.0 | | | | |
| | P | 53 | 26.18 | 20.99 | 2.0 | 115.0 | U | 2.9413 | 250.6 | 0.0036 |

[1]Variance

[2]Unequal

[3]Equal

Table 7. Number of correct and incorrect occurrence (spotted bass) classifications of stream sites in various river basins in Kansas.

| River basin* | Correct classifications | | Misclassification | |
|---|---|---|---|---|
| | Presence | Absence | Presence to Absence | Absence to Presence |
| Big Blue | - | 2 | - | - |
| Cimarron | - | - | - | - |
| Kansas | - | 7 | - | 2 |
| Little Arkansas | - | - | - | - |
| Lower Arkansas | 5 | 3 | - | 3 |
| Lower Republican | - | 21 | - | - |
| Marias des Cygnes | - | 1 | - | - |
| Missouri | - | - | - | - |
| Neosho | 14 | - | 2 | 2 |
| Saline | - | 4 | - | 1 |
| Smoky Hill | - | 2 | - | 4 |
| Solomon | - | 4 | - | 1 |
| Upper Arkansas | - | - | - | - |
| Upper Republican | - | - | - | - |
| Verdigris | 7 | - | - | 1 |
| Walnut | 15 | 3 | - | 5 |
| Totals | 41 | 47 | 2 | 19 |
| Totals | 88 | | 21 | |

*Numbers represent river basins shown on Figure 1.

able habitat in western reaches of the Lower Arkansas River Basin (Figure 4). This area may be inaccessible to spotted bass because of distance from other habitable areas.

The remaining ten sites where presence was incorrectly predicted are within the natural range of spotted bass. However, at each of these locations fish were collected only with seines. If comparative standing crops of fishes obtained by different sampling techniques are reliable as an estimator of collecting efficiency, seining appears to be a poor method for collecting spotted bass (Figure 5). Therefore, the data from these sites may not reflect the actual occurrence of this species.

The model accurately predicted presence or absence of spotted bass for 88 stream sites. Of the 21 misclassifications, 19 can be explained by zoogeographical distribution of the species or sampling method.

## Suitability Curves

Suitability curves were drawn for spotted bass for the following variables: mean depth, mean width, minimum width, nitrates, percent riffle, pH, turbidity, water temperature (Appendix A). Data used to prepare the curves are in Appendix I. Data for other variables related to spotted bass mean standing crops that did not lend themselves to construction of curves are in Appendix J.

## Biomass Models

A stepwise regression analysis was computed to explain standing crop of spotted bass. The curves (Appendix A) developed from the Kansas stream survey data were used to assign habitat suitability index

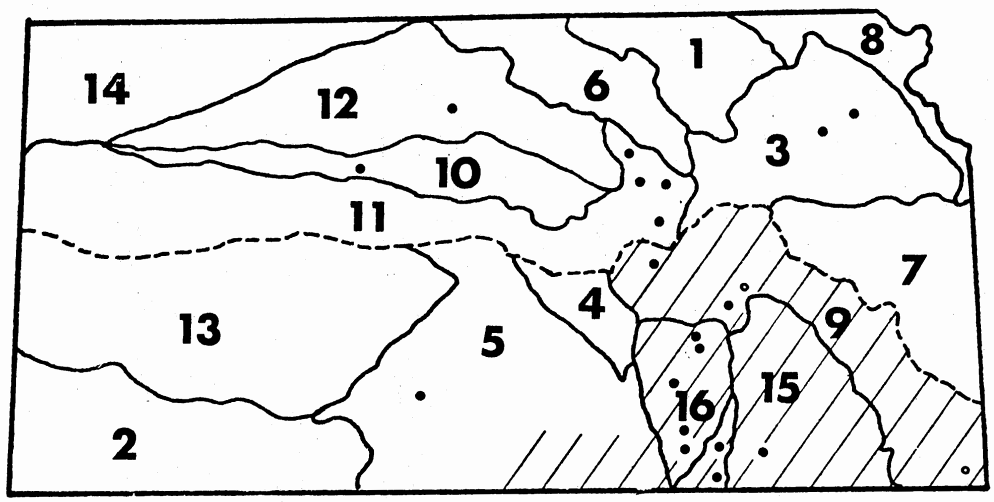


Figure 4. Map of Kansas showing stream sites containing spotted bass that were misclassified from presence-absence by the model. Numbers identify river basins (see Table 2). Misclassified sites from presence to absence are designated by a •. Those sites misclassified from absence to presence are represented by a o. Oblique lines designate the native range of spotted bass. The dotted line separates the Kansas River Basin (above the line) from the Arkansas River Basin (below the line).

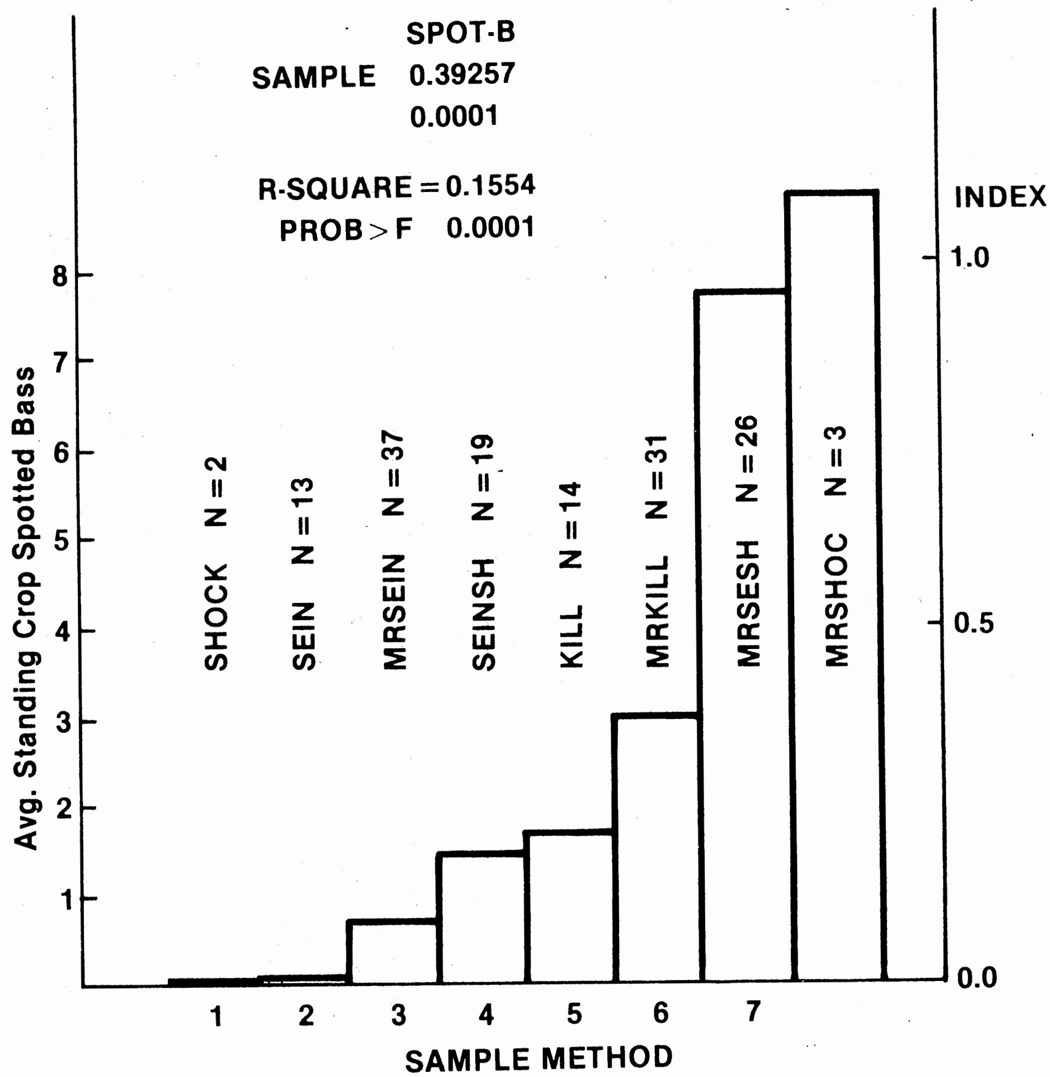


Figure 5. Average standing crops (kg/ha) for spotted bass collected by various sampling techniques. Only data from sites represented within the native range were used in the figure. Sample method codes: shock = shocking; sein = seining; mrsein = mark and recapture using seining; seinsh = seining and shocking; kill = rotenone; mrkill = rotenone with mark and recapture; mrsesh = seining and shocking with mark and recapture.

values to each stream site. Significant $r^2$ values were not obtained when the entire data set was used. However, when the data set was categorized by sampling techniques, significant $r^2$ values were obtained (Table 8).

When data obtained by sample method 7 was used, a low $r^2$ value was obtained and the relationship was not significant. Conversely, when the sample was collected by methods 3, 5, 6, 7, or 8, $r^2$ values were high and significant. Importance of variables explaining variation in standing crop also changed with sampling method.

## Testing the Models

Using the discriminant analysis from the Kansas data as a calibration data set, stream sites sampled in Oklahoma were classified into presence or absence groups for spotted bass. Fourteen sites were misclassified from absence into presence. Twenty-two sites where the species was not found were correctly classified. Only five of 14 sites where the species was found were correctly classified. A discriminant analysis was also performed on the Oklahoma data using the same variables that were used in the Kansas analysis. Only one site of the 50 was misclassified.

A significant correlation between predicted values based on Kansas data and observed standing crops in Oklahoma was not found. However, assigning suitability indices from the curves developed from the Kansas data and performing stepwise regression resulted in a significant model of standing crop in Oklahoma streams. The variables were added to the model as follows ($r^2$ value and significance level, respectively, in parentheses): turbidity (.29; .0464); mean depth (.49; .0235); minimum

Table 8. Results of stepwise multiple regressions relating spotted bass standing crops by collection method.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Kill technique with mark and recapture (sample method 6) | 16 | .86 | 9.78 | .0016 | Water temperature | 12.20 | .0082 |
| | | | | | Mean width | 2.61 | .1451 |
| | | | | | pH | 6.26 | .0368 |
| | | | | | Minimum width | 30.54 | .0006 |
| | | | | | Nitrates | 5.39 | .0488 |
| | | | | | Percent riffle | 3.90 | .0839 |
| | | | | | Mean depth | 2.61 | .1451 |
| Mark and recapture kill combined with kill technique used alone (sample methods 5 and 6 combined) | 19 | .71 | 5.05 | .0084 | Water temperature | 10.32 | .0075 |
| | | | | | Mean depth | 7.94 | .0155 |
| | | | | | Mean width | 6.96 | .0216 |
| | | | | | Minimum width | 11.46 | .0054 |
| | | | | | Nitrates | 3.45 | .0081 |
| | | | | | Percent riffle | 1.37 | .2654 |
| Mark and recapture seining used with shocking (sample method 7) | 21 | .09 | 0.31 | .8987 | Water temperature | 0.34 | .5688 |
| | | | | | Turbidity | 0.42 | .5298 |
| | | | | | Mean width | 0.41 | .5332 |
| | | | | | Minimum width | 0.53 | .4766 |
| | | | | | Nitrates | 0.20 | .6577 |
| Mark and recapture shocking (sample method 8) | 14 | .75 | 6.38 | .0012 | Water temperature | 3.42 | .1018 |
| | | | | | Turbidity | 2.56 | .1482 |
| | | | | | Mean depth | 15.67 | .0042 |
| | | | | | Minimum width | 1.77 | .2205 |
| | | | | | Percent riffle | 3.08 | .1172 |

Table 8. Continued.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture seining (sample method 3) | 12 | .92 | 6.85 | .0410 | Turbidity | 7.66 | .0495 |
| | | | | | Mean depth | 27.45 | .0063 |
| | | | | | Mean width | 23.25 | .0085 |
| | | | | | pH | 1.51 | .2869 |
| | | | | | Minimum width | 17.25 | .0142 |
| | | | | | Nitrates | 2.42 | .1949 |

width (.53; .0456); mean width (.69; .0198); pH (.84; .0054); percent riffle (.87; .0076); water temperature (.87; .0236).

## CHAPTER V

## RESULTS-SLENDERHEAD DARTER

### Species Occurrence Model

Several variables were important in predicting the occurrence of slenderhead darters and 100 percent of the 17 sites where slenderhead darters were found were classified correctly (Table 9). Of the 195 sites where slenderhead darters were not found, 164 were classified correctly. Twelve of the 31 misclassified sites lie outside the natural range of the fish (Figure 6). The following variables are listed in order from greatest to least importance in discriminating between presence and absence of slenderhead darters: runoff, gradient, percent pool, maximum width, mean width, chlorides, growing season, percent riffle, water temperature, percent run, and minimum width.

### Suitability Curves

Suitability curves were drawn for the slenderhead darter for the following variables: calcium hardness, chlorides, conductivity, dissolved oxygen, gradient, growing season, maximum width, mean depth, mean width, minimum width, nitrates, percent pool, percent riffle, pH, phosphates, run, runoff, sulfates, total alkalinity, total dissolved solids, turbidity, volume of flow, and water temperature (Appendix B). Data used to prepare the curves are in Appendix I. Data for additional variables are in Appendix J.

Table 9. Significant relationships between presence and absence groups of slenderhead darters (P = presence, A = absence) and physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Chlorides (mg/l) | A | 370 | 102.64 | 189.42 | 0.1 | 1870.0 | | | | |
| | P | 25 | 55.50 | 61.48 | 0.0 | 245.0 | U[2] | -2.9928 | 63.0 | 0.0039 |
| Gradient (m/km) | A | 340 | 1.51 | 1.12 | 0.1 | 7.9 | | | | |
| | P | 29 | 0.81 | 0.66 | 0.1 | 3.4 | U | 5.0906 | 43.3 | 0.0001 |
| Growing season (days) | A | 388 | 177.91 | 11.78 | 82.0 | 194.0 | | | | |
| | P | 32 | 187.15 | 5.86 | 179.0 | 193.0 | U | -7.7183 | 54.6 | 0.0001 |
| Maximum width (m) | A | 377 | 11.50 | 12.28 | 0.9 | 125.5 | | | | |
| | P | 28 | 18.61 | 9.16 | 7.6 | 45.4 | U | -3.8595 | 34.6 | 0.0005 |
| Mean width (m) | A | 388 | 9.07 | 10.87 | 0.9 | 110.3 | | | | |
| | P | 32 | 14.91 | 6.88 | 3.6 | 32.3 | U | -4.3743 | 44.9 | 0.0001 |
| Minimum width (m) | A | 378 | 6.14 | 8.75 | 0.3 | 101.1 | | | | |
| | P | 28 | 9.69 | 5.05 | 0.6 | 19.8 | U | -3.3647 | 40.2 | 0.0017 |
| Pool (%) | A | 379 | 41.50 | 40.23 | 0.0 | 100.0 | | | | |
| | P | 30 | 57.30 | 37.97 | 0.0 | 100.0 | E[3] | -2.0784 | 407.0 | 0.0383 |
| Riffle (%) | A | 377 | 8.98 | 16.27 | 0.0 | 100.0 | | | | |
| | P | 31 | 14.74 | 14.41 | 0.0 | 49.0 | U | -2.1172 | 36.6 | 0.0411 |
| Run (%) | A | 378 | 50.06 | 42.21 | 0.0 | 100.0 | | | | |
| | P | 30 | 27.73 | 39.90 | 0.0 | 100.0 | E | 2.7993 | 406.0 | 0.0054 |

Table 9. Continued.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Runoff (in/yr) | A | 388 | 1.84 | 1.76 | 0.1 | 10.0 | | | | |
| | P | 32 | 4.18 | 3.11 | 1.0 | 10.0 | U | -4.2020 | 32.7 | 0.0002 |
| Water temperature | A | 374 | 20.60 | 7.22 | 1.0 | 36.0 | | | | |
| (C) | P | 31 | 24.03 | 3.76 | 14.0 | 30.0 | U | -4.4390 | 50.7 | 0.0001 |

[1]Variance

[2]Unequal

[3]Equal

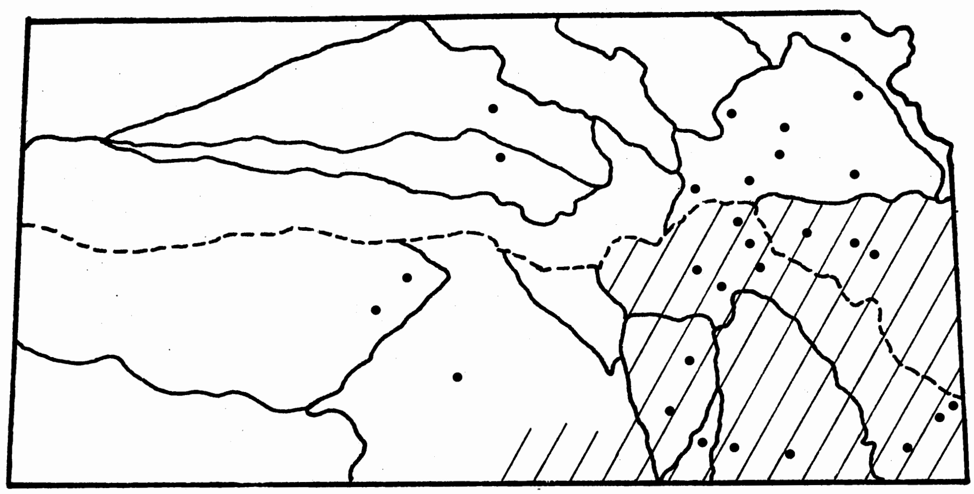

Figure 6. Map of Kansas showing stream sites that were misclassified by the model from absence to presence for slenderhead darters.

## Biomass Models

No significant relationship was found between average standing crops of slenderhead darters and sampling technique (Layher and Maughan 1981). However, a majority of the sites (13) where slenderhead darters occurred were sampled by method 6. Occurrence information obtained with other sampling techniques always involved five or fewer sites; therefore, only data from sites sampled by method 6 were used in model development. One variable, calcium hardness, explained 87.9 percent of the variation in standing crop. The model was significant at the .0001 level. Addition of the variable, percent riffle, increased the $r^2$ value to .915. The significance of the entire model remained the same. With the addition of the variable of maximum stream width the $r^2$ increased to .943, but again significance of the model remained .0001. Equations for the 1, 2, and 3 variable models are given below:

(1) −0.65 + 8.19 (calcium hardness SI) = slenderhead darter standing crops

| | |
|---|---|
| $r^2$ = .879 | PROB F = 0.0001 |

(2) −1.06874791 + 7.39817441 (calcium hardness SI) + 1.24387799 (% riffle SI) = slenderhead darter standing crop

| | |
|---|---|
| $r^2$ = .915 | PROB F = 0.0001 |
| Calcium hardness | PROB F = 0.0001 |
| % Riffle | PROB F = 0.0519 |

(3) −1.44162286 + 6.87672562 (calcium hardness SI) + 0.83166291 (maximum width SI) + 1.34153323 (% riffle SI) = slenderhead darter standing crop

| | |
|---|---|
| $r^2$ = .943 | PROB F = 0.0001 |
| Calcium hardness | PROB F = 0.0001 |
| Maximum width | PROB F = 0.0519 |
| % Riffle | PROB F = 0.215 |

Addition of other variables increased the $r^2$ of the model but also resulted in minor decreases in significance. However, additional individual variables themselves did not meet the .05 level of significance to be accepted as important or worthwhile additions to the model. Calcium hardness also appeared to be the most important variable in models developed for sites sampled by other methods.

## Testing the Models

Using the Kansas data as a calibration data set, in a discriminant analysis, stream sites sampled in Oklahoma were classified into presence or absence groups for slenderhead darters. A total of 37 sites where slenderhead darters were not found were properly classified. Two sites were misclassified from absence into the presence group. However, 81.9 percent of the eleven sites where slenderhead darters occurred were misclassified into the absence group.

A discriminant analysis was performed on the Oklahoma data using the same physical and chemical variables that were used in the Kansas analysis. Only one of the 50 was misclassified. This site (number 36, Big Creek, Nowata County) is within the range of the species in Oklahoma. The model placed the site in the presence group but we failed to capture the species.

A significant correlation was not obtained between predicted values based on Kansas data and observed standing crops of slenderhead darters in Oklahoma. However, when suitability index values were assigned for each variable for which curves had been drawn and a stepwise regression analysis made, a significant explanation of Oklahoma standing crops of this species was derived. The model was based on eleven sites where the species occurred. Three variables produced a $r^2$ of .79 with a significance level of .0197. Variables included in the model were maximum width, mean depth, and phosphates. The addition of total alkalinity increased the $r^2$ to .86 and the significance of the model changed to .0249. The further addition of water temperature to the model increased the $r^2$ to .996 with a significance level of .0001.

# CHAPTER VI

## RESULTS-ORANGETHROAT DARTER

### Species Occurrence Model

Ninety percent of the sites (45 of 50) were correctly predicted to contain orangethroat darters. Of 46 sites where orangethroat darters did not occur, only 30 sites (65.22 percent) were correctly predicted not to contain orangethroat darters. The explanation for misclassification of these 16 sites remains elusive. Small body size may make it unlikely that the darters will migrate into some isolated, yet suitable areas; however, the orangethroat darter is found throughout much of the eastern two-thirds of Kansas, and this does not appear to be a satisfactory explanation for misclassifications. Other explanations include the possibility that natural or man-induced eradication may have occurred at some sites, or that streams may have been sampled at times when variables measured were not indicative of normal stream conditions. The following variables are listed in order from greatest to least importance in discriminating between presence and absence of orangethroat darters: gradient, runoff, nitrates, chlorides, minimum width, turbidity, percent riffle, percent run, percent pool, sulfates, total dissolved solids, phosphates, and conductivity (Table 10).

Table 10. Significant relationships between presence and absence groups of orangethroat darters (P = presence, A = absence) and physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Chlorides (mg/l) | A | 255 | 125.80 | 216.00 | 0.5 | 1870.0 | | | | |
| | P | 140 | 52.00 | 86.10 | 0.1 | 665.0 | U[2] | -4.8065 | 366.2 | 0.0001 |
| Conductivity (μmhos/cm) | A | 139 | 1225.00 | 172.20 | 200.0 | | | | | |
| | P | 79 | 807.10 | 715.00 | 85.0 | 4000.0 | U | 3.2675 | 214.9 | 0.0013 |
| Gradient (m/km) | A | 233 | 1.28 | 1.03 | 0.1 | 7.9 | | | | |
| | P | 136 | 1.76 | 1.17 | 0.0 | 5.0 | U | -3.9282 | 255.8 | 0.0001 |
| Minimum width (m) | A | 260 | 7.10 | 10.20 | 0.3 | 101.1 | | | | |
| | P | 146 | 5.12 | 4.10 | 0.6 | 22.8 | U | 2.7547 | 374.7 | 0.0062 |
| Nitrates (mg/l) | A | 246 | 6.72 | 4.71 | 0.0 | 35.2 | | | | |
| | P | 138 | 8.82 | 10.52 | 0.0 | 92.4 | U | -2.2261 | 168.3 | 0.0273 |
| Phosphates (mg/l) | A | 256 | 0.69 | 1.03 | 0.0 | 9.0 | | | | |
| | P | 140 | 0.45 | 0.68 | 0.0 | 4.5 | U | 2.7364 | 379.3 | 0.0065 |
| Pool (%) | A | 258 | 38.97 | 41.28 | 0.0 | 100.0 | | | | |
| | P | 151 | 48.95 | 37.70 | 0.0 | 100.0 | E[3] | -2.4342 | 407.0 | 0.0154 |
| Riffle (%) | A | 257 | 7.97 | 16.02 | 0.0 | 100.0 | | | | |
| | P | 151 | 11.88 | 16.13 | 0.0 | 88.0 | E | -2.3672 | 406.0 | 0.0184 |
| Run (%) | A | 257 | 54.06 | 43.44 | 0.0 | 100.0 | | | | |
| | P | 151 | 38.81 | 38.84 | 0.0 | 100.0 | U | 3.6617 | 343.0 | 0.0003 |

Table 10. Continued.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Runoff (in/yr) | A | 268 | 1.49 | 1.62 | 0.1 | 10.0 | | | | |
| | P | 152 | 2.95 | 2.23 | 0.1 | 10.0 | U | -7.1082 | 242.9 | 0.0001 |
| Sulfates (mg/l) | A | 248 | 161.44 | 161.95 | 0.0 | 1250.0 | | | | |
| | P | 132 | 117.33 | 152.59 | 1.0 | 900.0 | E | 2.5788 | 378.0 | 0.0103 |
| Total dissolved solids (mg/l) | A | 137 | 571.26 | 595.51 | 22.0 | 4200.0 | | | | |
| | P | 73 | 363.04 | 329.49 | 34.0 | 1750.0 | U | 3.2615 | 207.7 | 0.0013 |
| Turbidity (JTU's) | A | 140 | 51.65 | 87.14 | 0.0 | 560.0 | | | | |
| | P | 113 | 29.03 | 56.50 | 0.0 | 510.0 | U | 2.4899 | 240.5 | 0.0135 |

[1]Variance

[2]Unequal

[3]Equal

## Suitability Curves

Suitability curves were drawn for the orangethroat darter for the following variables: calcium hardness, conductivity, dissolved oxygen, gradient, growing season, magnesium hardness, maximum width, mean depth, mean width, minimum width, nitrates, percent pool, percent riffle, percent run, pH, phosphates, runoff, sulfates, total alkalinity, turbidity, velocity, volume of flow, and water temperature (Appendix C). Data used to prepare suitability curves are in Appendix I. Data for additional variables for which curves were not drawn are in the Appendix J.

## Biomass Models

Sixteen sets of data from sample method 7 were available for model development. An $r^2$ of .64 was obtained utilizing five independent variables. Variables included in the model were mean width, minimum width, percent pool, percent run and total alkalinity. All variables were significant below the .0095 level. The entire model was significant at the .0269 level ($F = 3.95$). Four additional variables; conductivity, magnesium hardness, riffle and sulfates, added to the model increased the $r^2$ value to .9490 ($F = 14.49$; $p > F = .001$). All nine variables were significantly correlated with biomass ($p < .008$). Values of F for individual variables ranged from 13.57 for total alkalinity (the lowest F value) to 73.32 (the highest) for percent run. Two additional variables, dissolved oxygen and turbidity increased the model $r^2$ to .98 ($F = 36.53$; $p > F = .0005$). Both variables were significant below the .05 level.

Sixty-three stream sites sampled by method 6 were available for model development. Five independent variables produced an $r^2$ of .3906 ($F = 7.44$; $p > F = .0001$). Only three of the variables, magnesium hardness, nitrates and phosphates were significant at the .05 level. Dissolved oxygen and maximum width were the other two variables included in the model. Significance levels were .1394 and .1996 respectively for these variables. Additional variables were added to the model to produce an $r^2$ of .4993 ($F = 2.00$; $p > F = .0282$). However, only phosphates and magnesium hardness of these additional variables were significant at the .05 level.

Complete data for 23 sites sampled by method 5 were available. Four variables, conductivity, growing season, nitrates and turbidity produced an $r^2$ of .6259 ($F = 7.95$; $p > F = .0006$). The variables were all significant at the .05 level. F values for individual variables in the model ranged from 3.52 for turbidity to 28.40 for nitrates. Addition of the variables, mean depth, mean width, and total alkalinity, increased the $r^2$ of the model to .7230 ($F = 5.97$; $p > F = .0015$). Significance levels for the last three variables were .0736, .1981, and .1025 respectively. The significance level of all of the four other variables remained below .0303 an $r^2$ of .8830 was obtained by adding data on additional variables; however, the model was no longer significant at the .05 level. The model did remain significant at the .0356 level with an F of 3.63 with a total of 15 independent variables and an $r^2$ of .8719.

Data from 11 sites sampled by method 4 were used to develop a standing crop model. Mean depth was the only variable that was significant at the .05 level ($F = 4.78$; $r^2 = .3236$).

Twenty sites were sampled by method 3. Nine variables, all significant at the .0019 level produced at $r^2$ of .9254 ($F = 18.63$; $p > F = .0001$). Stepwise addition of these variables to the model produced the following results ($r^2$ for the entire model given in parentheses): phosphates (.3065); percent pool (.5381); minimum width (.6394); conductivity (.7202); growing season (.7699); nitrates (.8129); percent riffle (.8556); magnesium hardness (.8860); nitrates removed and replaced by turbidity (.9158); and minimum width removed and replaced by mean width (.9254).

Ten sites were sampled by method 2. Five variables produced a model explaining standing crop with an $r^2$ of .9721 ($p > F = .0007$). All variables were significant below the .04 level. Stepwise addition of the variables produced the following model ($r^2$ for the entire model given in parentheses): water temperature (.2234); sulfates (.5941); percent pool (.8790); total alkalinity (.9323); and calcium hardness (.9721).

All sites sampled by method 4 had at least one variable missing from the data set. In addition no data was available for sites sampled by method 7 or 8. Consequently no model was developed for data from these techniques of capture. Regression models are summarized in Table 11.

## Testing the Models

Using the Kansas data set as a calibration data set for discriminant analysis, stream sites sampled in Oklahoma were classified into presence or absence groups for orangethroat darters. Twenty-five of 38 sites were misclassified and incorrectly placed into the presence group

Table 11. Results of stepwise multiple regressions relating orangethroat darter standing crops by collection method.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture shocking (sample method 8) | 16 | .64 | 3.95 | .0269 | Mean width | 12.68 | .0045 |
| | | | | | Minimum width | 10.63 | .0076 |
| | | | | | Percent pool | 9.81 | .0075 |
| | | | | | Percent run | 14.61 | .0028 |
| | | | | | Total alkalinity | 1.49 | .2484 |
| Kill technique with mark and recapture (sample method 6) | 63 | .39 | 7.44 | .0001 | Magnesium hardness | 3.82 | .0555 |
| | | | | | Nitrates | 6.72 | .0120 |
| | | | | | Phosphates | 30.90 | .0001 |
| | | | | | Dissolved oxygen | 2.25 | .1394 |
| | | | | | Mean width | 1.68 | .1996 |
| Kill technique without mark and recapture (sample method 5) | 23 | .62 | 7.95 | .0006 | Conductivity | 5.90 | .0252 |
| | | | | | Growing season | 9.02 | .0073 |
| | | | | | Nitrates | 28.40 | .0001 |
| | | | | | Turbidity | 3.52 | .0761 |
| Seining and shocking (sample method 4) | 11 | .32 | 4.78 | .0536 | Mean depth | | |
| Mark and recapture seining (sample method 3) | 20 | .92 | 18.63 | .0001 | Phosphates | 62.92 | .0001 |
| | | | | | Percent pool | 71.29 | .0001 |
| | | | | | Conductivity | 23.12 | .0004 |
| | | | | | Growing season | 18.19 | .0011 |
| | | | | | Percent riffle | 21.60 | .0006 |
| | | | | | Magnesium hardness | 29.92 | .0001 |
| | | | | | Turbidity | 23.37 | .0004 |
| | | | | | Mean width | 15.60 | .0019 |

Table 11. Continued.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Seining (sample method 2) | 10 | .97 | 34.90 | .0007 | Water temperature | 138.26 | .0001 |
| | | | | | Sulfates | 113.50 | .0001 |
| | | | | | Percent pool | 40.58 | .0014 |
| | | | | | Total alkalinity | 10.97 | .0212 |
| | | | | | Calcium hardness | 7.15 | .0441 |

when sampling indicated that the species did not occur. Of the 12 remaining sites, seven were properly placed in the presence group.

When a discriminant analysis was performed on the Oklahoma data using the same physical and chemical variables that were used in the Kansas analysis, all but one site was correctly classified. This site (number 34, Sycamore Creek in Osage County) was misclassified into the presence group.

No significant correlations were found between predicted values based on equations developed from Kansas data and observed standing crops in Oklahoma streams. However, when suitability index values were assigned to each Oklahoma site; significant regression models were obtained. Three variables explained 75 percent of the variation in standing crop at 12 sample sites. The significance level for the regression model was .0090. Variables in order of importance in explaining variation in orangethroat darter standing crop were percent run, gradient and runoff. The addition of mean depth increased the $r^2$ to .84; the addition of conductivity increased the $r^2$ to .88. In both cases, the significance level was less than .01. Additional variables increased the $r^2$ value without a reduction in model significance.

# CHAPTER VII

# RESULTS-CENTRAL STONEROLLER

## Species Occurrence Model

Of the 42 sites where central stonerollers did not occur, 38 were classified correctly. Of the 52 sites where central stonerollers were found, 36 were classified correctly. Of 94 sites with complete data sets, 74 were classified correctly. The following variables are listed in order from greatest to least importance in discriminating between presence and absence of central stonerollers: runoff, gradient, nitrates, turbidity, mean width, volume of flow, maximum width, mean depth, calcium hardness, total hardness, minimum width, and phosphates (Table 12).

## Suitability Curves

Suitability curves for the following variables were drawn for the central stoneroller: chlorides, conductivity, dissolved oxygen, gradient, magnesium hardness, maximum width, mean depth, mean width, minimum width, nitrates, percent pool, percent riffle, percent run, pH, phosphates, sulfates, total alkalinity, total dissolved solids, turbidity, velocity, volume of flow, and water temperature (Appendix D). Data used to prepare suitability curves are in Appendix I. Data for additional variables for which curves were not drawn are summarized in the Appendix J.

Table 12. Significant relationships between presence and absence groups of central stonerollers (P = presence, A = absence) and physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Calcium hardness | A | 193 | 235.82 | 125.53 | 10.0 | 850.0 | | | | |
| (mg/l) | P | 180 | 270.67 | 186.24 | 0.0 | 1350.0 | U[2] | -2.1039 | 310.8 | 0.0362 |
| Gradient (m/km) | A | 183 | 1.24 | 0.97 | 0.1 | 5.0 | | | | |
| | P | 186 | 1.67 | 1.19 | 0.1 | 7.9 | U | -3.7415 | 354.8 | 0.0002 |
| Maximum width (m) | A | 206 | 13.48 | 15.48 | 1.2 | 125.5 | | | | |
| | P | 199 | 10.44 | 7.17 | 0.9 | 42.6 | U | 2.5169 | 291.3 | 0.0114 |
| Mean depth (m) | A | 212 | 0.55 | 0.43 | 0.1 | 4.5 | | | | |
| | P | 208 | 0.44 | 0.34 | 0.1 | 3.1 | U | 2.9928 | 403.2 | 0.0029 |
| Mean width (m) | A | 212 | 10.68 | 13.54 | 0.9 | 110.0 | | | | |
| | P | 208 | 8.32 | 6.56 | 0.9 | 45.7 | U | 2.2829 | 306.3 | 0.0231 |
| Minimum width (m) | A | 206 | 7.65 | 11.25 | 0.6 | 101.1 | | | | |
| | P | 200 | 5.09 | 4.05 | 0.3 | 27.4 | U | 3.0678 | 258.9 | 0.0024 |
| Nitrates (mg/l) | A | 197 | 6.41 | 3.95 | 0.0 | 34.3 | | | | |
| | P | 187 | 8.59 | 9.69 | 0.0 | 92.4 | U | -2.8564 | 243.6 | 0.0047 |
| Phosphates (mg/l) | A | 206 | 0.70 | 1.09 | 0.0 | 9.0 | | | | |
| | P | 190 | 0.50 | 0.68 | 0.0 | 4.5 | U | 2.2168 | 348.1 | 0.0271 |
| Runoff (in/yr) | A | 212 | 1.56 | 1.66 | 0.1 | 10.0 | | | | |
| | P | 208 | 2.48 | 2.18 | 0.1 | 10.0 | U | -4.8621 | 387.7 | 0.0001 |

Table 12. Continued.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Total dissolved | A | 104 | 596.51 | 567.95 | 22.0 | 3590.0 | | | | |
| solids (mg/l) | P | 106 | 403.08 | 467.23 | 34.0 | 4200.0 | U | 2.6925 | 199.1 | 0.0077 |
| Turbidity (JTU's) | A | 116 | 55.35 | 95.63 | 0.0 | 560.0 | | | | |
| | P | 137 | 29.86 | 50.90 | 0.0 | 510.0 | U | 2.5782 | 168.6 | 0.0108 |
| Volume of flow | A | 187 | 1.24 | 4.05 | 0.0 | 28.3 | | | | |
| ($m^3$/sec) | P | 190 | 0.57 | 2.03 | 0.0 | 25.1 | U | 2.0370 | 272.9 | 0.0426 |

[1]Variance

[2]Unequal

## Biomass Models

A complete data set was available for 18 sites that had been sampled by method 7. A model based on five variables resulted in an explanation of standing crop with an $r^2$ of .9020 ($F = 24.18$; $p > F = .0001$). Variables were entered into the model in a stepwise manner in the following order ($r^2$ for the entire model given in parentheses): mean width (.5670); percent run (.6988); magnesium hardness (.7644); sulfates (.8744); and pH (.9029). All variables in the model were significant at the .006 level with the exception of pH which was significant at the .0730 level.

Data sets were available from 85 sample sites sampled by method 6. A model based on 8 variables resulted in an $r^2$ of .5012 ($F = 9.67$; $p > F = .0001$). The variables were entered into the model in the following sequence ($r^2$ for the entire model given in parentheses): mean width (.1996); gradient (.2870); pH (.2924); water temperature (.3602); maximum width (.4138); mean depth (.4356); total dissolved solids (.4609); phosphates (.4835); and total alkalinity (.5012). All variables were significant in the model at the .03 level with the exception of phosphates (.1238) and alkalinity (.0609). The addition of 13 more independent variables produced an $r^2$ of only .5665 ($p > F = .0001$).

Data sets were available for 35 stations where sampling was made by method 5. Variables added in a stepwise manner in the following order produced the $r^2$ values given in parentheses: magnesium hardness (.1761); maximum width (.3019); nitrates (.4178); maximum width replaced by mean width (.4281); percent pool (.4723); dissolved oxygen

(.5203); and mean width replaced by maximum width (.5397). The five variable model had an F value of 7.04 with a significance level of .0002. All variables in the model were significant at the .05 level. Additional variables improved the $r^2$ of the model but lowered its significance level.

Complete data sets were available for 13 stream sites sampled by method 4. A model based on three variables resulted in an $r^2$ of .8821 ($F = 24.95$; $p > F = .001$). The three variables added in a stepwise manner resulted in the $r^2$ values given in parentheses: percent riffle (.5657); sulfates (.7868); and pH (.8821). All three variables were significant at the .01 level. A model based on six variables, chlorides, gradient, mean width, phosphates, sulfates, and velocity, produced an $r^2$ of .9980 ($F = 125.89$; $p > F = .001$). All individual variables were significant below the .007 level except chlorides which had a significance level of .1137.

Complete data sets were available for 23 sample sites sampled by method 3. Three variables produced an $r^2$ of .7406 ($F = 19.04$; $p > F = .0001$). The three variables were all significant below the .0203 level. The three variables were entered into the model in a stepwise manner and produced the $r^2$ values given in parentheses: percent run (.5282); water temperature (.6582) and gradient (.7406). Additional variables increased the $r^2$ value of the model but their importance was questionable because of the lowered degrees of freedom.

Data sets were available for 21 sample sites when sample method 2 was used. Three variables, mean width, maximum width and phosphates, produced an $r^2$ of .7815 ($F = 21.46$; $p > F = .0001$).

No complete observations were available to produce models based on sites sampled by method 8. The models produced by various sampling techniques are summarized in Table 13.

## Testing the Models

Poor results were obtained using the Kansas data as a calibration data set for predicting presence or absence of stonerollers for stream sites in Oklahoma. Thirty-four sites were misclassified into the presence group. Three sites were misclassified into the absence group. Ten sites where the central stoneroller did not occur were classified correctly while three sites where the species did occur were classified correctly.

A discriminant analysis was performed on the Oklahoma data using the same physical and chemical variables that were used in the Kansas analysis. Only five sites were misclassified from absence into the presence group. All six sites where the species actually occurred were classified properly.

No significant correlations were obtained between predicted and observed standing crops of central stonerollers. However, assigning suitability values for stream characteristics and performing a stepwise regression analysis resulted in an $r^2$ of .60 with a level of significance of .06. The most important variable in explaining standing crop was mean depth. Maximum width and water temperature increased the $r^2$ to .99 with a significance level of .0070.

Table 13. Results of stepwise multiple regressions relating central stoneroller standing crops by collection method.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture seining and shocking (sample method 7) | 18 | .90 | 24.18 | .0001 | Mean width | 90.43 | .0001 |
| | | | | | Percent run | 10.71 | .0061 |
| | | | | | Magnesium hardness | 17.85 | .0010 |
| | | | | | Sulfates | 15.15 | .0019 |
| | | | | | pH | 3.81 | .0730 |
| Mark and recapture with a final kill technique (sample method 6) | 85 | .50 | 9.67 | .0001 | Mean width | 9.73 | .0025 |
| | | | | | Gradient | 14.42 | .0003 |
| | | | | | pH | 6.22 | .0148 |
| | | | | | Water temperature | 4.89 | .0301 |
| | | | | | Mean depth | 7.49 | .0077 |
| | | | | | Total dissolved solids | 7.00 | .0099 |
| | | | | | Phosphates | 2.42 | .1238 |
| | | | | | Total alkalinity | 3.62 | .0609 |
| Kill technique without mark and recapture (sample method 5) | 35 | .53 | 7.04 | .0002 | Magnesium hardness | 12.72 | .0012 |
| | | | | | Maximum width | 9.07 | .0052 |
| | | | | | Nitrates | 7.62 | .0078 |
| | | | | | Percent pool | 4.14 | .0507 |
| | | | | | Dissolved oxygen | 4.79 | .0366 |
| Seining and shocking (sample method 4) | 13 | .88 | 24.95 | .0010 | Percent riffle | 52.53 | .0001 |
| | | | | | Sulfates | 21.78 | .0009 |
| | | | | | pH | 8.09 | .0174 |

Table 13. Continued.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture seining (sample method 3) | 23 | .74 | 19.04 | .0001 | Percent run | 18.30 | .0004 |
| | | | | | Water temperature | 15.48 | .0008 |
| | | | | | Gradient | 6.35 | .0203 |
| Seining (sample method 2) | 21 | .78 | 21.46 | .0001 | Mean width | 51.75 | .0001 |
| | | | | | Maximum width | 12.78 | .0022 |
| | | | | | Phosphates | 9.91 | .0056 |

# CHAPTER VIII

## RESULTS-CHANNEL CATFISH

### Species Occurrence Model

Of 153 sample sites where channel catfish were not collected, 135 or 88.24 percent were classified correctly. However, of 152 sample sites where channel catfish were collected, only 61 sites or 40.13 percent were classified correctly. Overall, 64.26 percent of all sites were classified into the proper group based on species occurrence. The following variables are listed in order from greatest to least importance in discriminating between presence and absence of channel catfish: maximum width, water temperature, gradient, mean depth, percent riffle, mean width, minimum width, maximum width, and volume of flow (Table 14).

### Suitability Curves

Suitability curves were drawn for the channel catfish for the following variables: conductivity, dissolved oxygen, gradient, maximum width, mean depth, mean width, minimum width, nitrates, percent pool, percent riffle, percent run, pH, runoff, sulfates, total alkalinity, total dissolved solids, turbidity, volume of flow, and water temperature (Appendix E). Data used to develop suitability curves are in Appendix I. Data for additional variables for which suitability curves were not drawn are in Appendix J.

Table 14. Significant relationships between presence and absence groups of channel catfish (P = presence, A = absence) and physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Gradient (m/km) | A | 171 | 1.77 | 1.18 | 0.1 | 7.9 | | | | |
| | P | 198 | 1.19 | 0.96 | 0.1 | 5.0 | U[2] | 5.0630 | 327.7 | 0.0001 |
| Maximum width (m) | A | 209 | 8.65 | 8.71 | 0.9 | 91.4 | | | | |
| | P | 196 | 15.55 | 14.26 | 2.4 | 125.5 | U | -5.8249 | 318.7 | 0.0001 |
| Mean depth (m) | A | 211 | 0.45 | 0.44 | 0.1 | 4.5 | | | | |
| | P | 209 | 0.54 | 0.33 | 0.1 | 2.1 | U | -2.2236 | 389.9 | 0.0267 |
| Mean width (m) | A | 211 | 6.70 | 7.42 | 0.9 | 76.2 | | | | |
| | P | 209 | 12.35 | 12.65 | 1.8 | 110.0 | U | -5.5738 | 335.4 | 0.0001 |
| Minimum width (m) | A | 210 | 4.56 | 4.87 | 0.3 | 54.8 | | | | |
| | P | 196 | 8.35 | 10.96 | 0.6 | 101.1 | U | -4.4433 | 265.2 | 0.0001 |
| Riffle (%) | A | 210 | 6.48 | 13.59 | 0.0 | 81.0 | | | | |
| | P | 198 | 12.53 | 18.07 | 0.0 | 100.0 | U | -3.8003 | 365.2 | 0.0002 |

[1]Variance

[2]Unequal

## Biomass Models

Ten stream sites sampled by method 5 had complete data sets. A model based on three variables had an $r^2$ of .6617 ($F = 4.56$; $p > F = .0450$). Variables entered in a stepwise fashion used to produce the model are as follows ($r^2$ of the entire model and individual variable significance levels are in parentheses): percent pool (.2376, .0136); minimum width (.5035, .0230); and conductivity (.6617, .1133).

Forty-two sites where channel catfish were collected by method 6 contained complete data sets. The model based on the independent variables percent run, runoff, water temperature, and maximum width has an $r^2$ of .4985 ($F = 9.20$; $p > F = .0001$). All variables in the model were significant at the .05 level with the exception of maximum width (.1199). If maximum width was removed, the model $r^2$ was reduced to .4641 ($F = 10.97$; $p > F = .0001$).

Complete data sets were available for 12 sites where sample method 7 was used, at six sites where sample method 4 was used, and at 11 sites using method 8. Percent of pool was the most important variable explaining channel catfish standing crop for the method 7 while gradient was the most important variable with sampling methods 4 and 8. Because of the small numbers of sites sampled with each of these methods, models explaining standing crop are not presented.

Complete data sets were available from only seven sites sampled by method 3. Conductivity was the most important variable explaining standing crop. A model is not presented because of the paucity of available data points. Method 1 and 2 used separately only provided two and four data points respectively and consequently, analysis was not performed. These models are summarized in Table 15.

Table 15. Results of stepwise multiple regressions relating channel catfish standing crops by collection method.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture with a final kill technique (sample method 6) | 42 | .49 | 9.20 | .0001 | Maximum width | 2.53 | .1199 |
| | | | | | Runoff | 10.65 | .0024 |
| | | | | | Percent run | 13.82 | .0007 |
| | | | | | Water temperature | 3.89 | .0560 |
| Kill technique used without mark and recapture (sample method 5) | 11 | .66 | 9.56 | .0450 | Conductivity | 3.27 | .1133 |
| | | | | | Minimum width | 8.41 | .0230 |
| | | | | | Percent pool | 10.72 | .0136 |
| Mark and recapture with kill combined with kill stations (sample method 5 and 6) | 53 | .38 | 4.88 | .0006 | Maximum width | 3.02 | .0892 |
| | | | | | Nitrates | 3.00 | .0901 |
| | | | | | Percent pool | 4.38 | .0419 |
| | | | | | Runoff | 2.29 | .1366 |
| | | | | | Percent run | 4.10 | .0487 |
| | | | | | Total alkalinity | 3.86 | .0556 |
| Mark and recapture seining and shocking (sample method 7) | 13 | .72 | 7.94 | .0067 | Percent pool | 16.83 | .0074 |
| | | | | | Runoff | 2.75 | .1315 |
| Mark and recapture shocking (sample method 8) | 12 | .68 | 5.83 | .0206 | Dissolved oxygen | 5.11 | .0536 |
| | | | | | pH | 2.88 | .1284 |
| | | | | | Gradient | 7.25 | .0274 |
| Seining and shocking (sample method 4) | 6 | .99 | 129.31 | .0011 | pH | 5.68 | .0974 |
| | | | | | Percent pool | 5.27 | .1054 |
| | | | | | Gradient | 318.97 | .0004 |

Table 15.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture seining (sample method 3) | 7 | .49 | 2.48 | .1787 | Conductivity | 4.95 | .0766 |
| | | | | | Dissolved oxygen | 1.00 | .3638 |

## Testing the Models

Using the Kansas data as a calibration data set, stream sites sampled in Oklahoma were classified into presence and absence groups for channel catfish by discriminant analysis. Nine of 27 sites where the species was not found were misclassified into the presence group. Eighteen of 23 sites where the species was found were misclassified into the absence group.

A discriminant analysis was performed on the Oklahoma data using the same physical and chemical variables that were used in the Kansas analysis. Seven of 27 sites were incorrectly placed in the presence group. Four of 19 sites where the species did occur were also misclassified.

The regression equation developed from Kansas survey sites based on sample method 6 showed a significant correlation between predicted and observed biomass values for Oklahoma sites. The Pearson correlation coefficient was .52 with a significance level of .0107, The N value was 23.

Assigning suitability values for each physical and chemical stream attribute to each Oklahoma site and performing stepwise regression also produced a significant model. The $r^2$ obtained with 10 variables was .74 ($p > F = .0386$). The variable percent riffle produced an $r^2$ of .48 ($p > F = .0003$). Other variables in order of importance in the 10 variable model were conductivity, turbidity, gradient, pH, total dissolved oxygen, sulfates, percent pool and runoff.

# CHAPTER IX

## RESULTS-LARGEMOUTH BASS

### Species Occurrence Model

There were 171 complete data sets from Kansas relating physical factors to standing crop of largemouth bass. Classification was correct in 108 cases or 63 percent of the observations. Of these sites 61 actually contained largemouth bass. The model correctly predicted occurrence at 55 sites or 90 percent. However, of the 110 sites where largemouth bass were not found, the model correctly predicted species absence at only 48 percent of these sites. Effectiveness improved when velocity was added to the model. With this model (N = 161) 45 of 55 sites containing largemouth bass were classified correctly; a reduction of about 8 percent in correct predictions. However, of 106 sites where largemouth bass were not found, 77 or 72.67 percent were classified correctly; an improvement of about 13 percent. The following variables are listed in order from greatest to least importance in discriminating between presence and absence of largemouth bass: chlorides, water temperature, percent run, maximum width, conductivity, gradient, velocity, calcium hardness, percent pool, percent riffle, and mean depth (Table 16).

### Suitability Curves

Suitability curves were drawn for the largemouth bass for the

Table 16. Significant relationships between presence and absence groups of largemouth bass (P = presence, A = absence) and physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Calcium hardness | A | 228 | 265.36 | 149.24 | 5.0 | 930.0 | | | | |
| (mg/l) | P | 145 | 232.64 | 170.71 | 0.0 | 1350.0 | U[2] | 1.8936 | 276.6 | 0.0593 |
| Chlorides (mg/l) | A | 240 | 117.23 | 179.66 | 0.5 | 1250.0 | | | | |
| | P | 155 | 72.45 | 188.63 | 0.1 | 1870.0 | E[3] | 2.3717 | 393.0 | 0.0182 |
| Conductivity | A | 137 | 1183.63 | 1066.25 | 85.0 | 910.0 | | | | |
| (μmhos/cm) | P | 81 | 887.27 | 955.07 | 200.0 | 6400.0 | U | 2.0687 | 177.4 | 0.0400 |
| Gradient (m/km) | A | 221 | 1.32 | 0.96 | 0.1 | 5.0 | | | | |
| | P | 148 | 1.67 | 1.27 | 0.1 | 7.9 | U | -2.8731 | 257.3 | 0.0044 |
| Maximum width (m) | A | 248 | 10.94 | 11.54 | 0.9 | 91.4 | | | | |
| | P | 157 | 13.65 | 13.06 | 3.0 | 125.5 | U | -2.1281 | 301.8 | 0.0341 |
| Mean depth (m) | A | 257 | 0.45 | 0.42 | 0.1 | 4.5 | | | | |
| | P | 163 | 0.57 | 0.33 | 0.1 | 2.1 | U | -3.3202 | 400.8 | 0.0010 |
| Pool (%) | A | 246 | 35.50 | 39.70 | 0.0 | 100.0 | | | | |
| | P | 163 | 53.46 | 38.72 | 0.0 | 100.0 | E | -4.5221 | 407.0 | 0.0001 |
| Riffle (%) | A | 247 | 8.14 | 15.89 | 0.0 | 100.0 | | | | |
| | P | 161 | 11.37 | 16.49 | 0.0 | 88.0 | E | -1.9809 | 406.0 | 0.0483 |
| Run (%) | A | 248 | 56.42 | 42.47 | 0.0 | 100.0 | | | | |
| | P | 160 | 36.01 | 39.30 | 0.0 | 100.0 | E | 4.8783 | 406.0 | 0.0001 |

Table 16. Continued.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Water temperature | A | 248 | 19.08 | 7.01 | 1.0 | 32.0 | | | | |
| (C) | P | 157 | 23.36 | 4.98 | 1.0 | 36.0 | U | -7.1752 | 397.6 | 0.0001 |

[1]Variance

[2]Unequal

[3]Equal

following variables: chlorides, conductivity, dissolved oxygen, gradient, growing season, maximum width, mean depth, mean width, minimum width, nitrates, percent pool, percent riffle, percent run, pH, phosphates, total alkalinity, total dissolved solids, turbidity, velocity, and water temperature (Appendix F). Data used to prepare suitability curves are in Appendix I. Data for additional variables for which curves were not drawn are in Appendix J.

## Biomass Models

Complete data sets were available for 53 sites where sample method 6 was used. Mean width and mean depth were the most important variables explaining largemouth bass standing crop with this capture technique. Both variables were significant at the .01 level but together produced a model $r^2$ of .1951 ($F = 6.18$; $p > F = .0039$).

Sample method 5 was used at 16 sites. Only total alkalinity and secchi disc reading met the .5 significance level for entry into the model (model $r^2 = .3246$; $p > F = .0629$).

No data were available to develop a model for method 1 and only two sites sampled by method 8 contained complete observations.

Fourteen observations were collected using method 4. In the model based on data from method 4 pH alone produced an $r^2$ of .9091 ($F = 130.08$; $P > F = .0001$). Addition of mean depth and total alkalinity increased the $r^2$ value of .9478 without affecting the significance level of the model. Significance levels for the three variables pH, mean depth, total alkalinity were .0001, .0284, and .0977, respectively.

Sixteen observations were available where sample method 7 was used. Percent run and water temperature were the two most important variables in this model but together only produced an $r^2$ of .35.

Thirteen observations where method 2 was used resulted in a model with an $r^2$ of .9008 ($p > F = .0001$). Three variables, turbidity, conductivity, and phosphates, were most important in this model. Each variable was added in a stepwise procedure and produced the following model $r^2$ values: .4611, .8533, and .9008. Significance levels for the three variables individually were .0001 except for phosphates which was .0580. A summary of the regression models is shown in Table 17.

## Testing the Models

Stream sites sampled in Oklahoma were classified into presence or absence groups for largemouth bass by using the Kansas data as a calibration data set in a discriminant function analysis. Thirteen of 19 sites where the species was not found were correctly placed into the absence group. Twenty of 31 sites where the species occurred were also correctly classified.

A discriminant analysis using the Oklahoma data as a calibration data set was performed on the Oklahoma data using the same physical and chemical variables that were used in the Kansas analysis. Only two sites of 19 were incorrectly placed in the presence group. Six of 31 sites were misclassified into the absence group. Approximately 84 percent of the sites were correctly classified.

Two significant Spearman correlation coefficients were found between predicted and observed standing crops of largemouth bass. A correlation of .4237, significant at the .0175 level was found between observed standing crops in Oklahoma streams and predicted standing crops based on Kansas stream survey data where standing crop estimates were

Table 17. Results of stepwise multiple regressions relating largemouth bass standing crops by collection method.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture with a final kill technique (method 6) | 53 | .19 | 6.18 | .0039 | Mean width | 5.89 | .0188 |
| | | | | | Mean depth | 5.83 | .0194 |
| Kill technique without mark and recapture (method 5) | 16 | .32 | 3.39 | .0629 | Total alkalinity | 4.64 | .0492 |
| | | | | | Secchi disc | 5.77 | .0307 |
| Seining and shocking (method 4) | 14 | .90 | 130.08 | .0001 | pH | | |
| Mark and recapture seining and shocking (method 7) | 16 | .35 | 3.90 | .0450 | Percent run | 4.93 | .0433 |
| | | | | | Water temperature | 2.15 | .1645 |
| Seining (method 2) | 13 | .90 | 30.27 | .0001 | Turbidity | 64.55 | .0001 |
| | | | | | Conductivity | 41.86 | .0001 |
| | | | | | Phosphates | 4.58 | .0580 |
| Mark and recapture seining (method 3) | 21 | .71 | 10.49 | .0001 | Gradient | 16.43 | .0008 |
| | | | | | pH | 12.39 | .0026 |
| | | | | | Nitrates | 13.70 | .0018 |
| | | | | | Turbidity | 2.14 | .1613 |

the result of method 6. The regression equation developed from method 7 also predicted standing crops significantly correlated to observed standing crops in Oklahoma streams. The correlation coefficient for this relationship was .4828 with a significance level of .0059. The N value in both cases was 31.

Utilizing suitability curves to assign index values to Oklahoma sites and performing stepwise regression produced an $r^2$ of .60 ($p > F =$ .0085). Variables entered into the model to produce this model were in order: mean depth, total alkalinity, water temperature, dissolved oxygen, total dissolved solids, turbidity, percent run, velocity, and gradient.

## CHAPTER X

## RESULTS-WHITE CRAPPIE

### Species Occurrence Model

Fifty-eight percent of 180 sites from the Kansas stream survey were correctly classified based on presence and absence of white crappie. Thirty-three, or 89 percent, of 37 sites where crappie were found were correctly placed in the presence groups. However, only 49.65 percent of those sites where crappie were absent were predicted correctly. The following variables are listed in order from greatest to least importance in discriminating between presence and absence of white crappie: total dissolved solids, gradient, water temperature, minimum width, mean width, maximum width, conductivity, and mean depth (Table 18).

### Suitability Curves

Suitability curves were drawn for the white crappie for the following variables: conductivity, dissolved oxygen, gradient, growing season, magnesium hardness, maximum width, mean depth, mean width, nitrates, pH, phosphates, percent riffle, turbidity, velocity, volume of flow, and water temperature (Appendix G). Data used to prepare suitability curves are in Appendix I. Data for additional variables for which curves were not drawn, are summarized in Appendix J.

Table 18. Significant relationships between presence and absence groups of white crappie (P = presence, A = absence) and physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Conductivity | A | 173 | 1179.46 | 1127.55 | 145.0 | 9100.0 | | | | |
| (µmhos/cm) | P | 45 | 666.22 | 481.92 | 85.0 | 2700.0 | U[2] | 4.5887 | 170.2 | 0.0001 |
| Gradient (m/km) | A | 289 | 1.53 | 1.12 | 0.1 | 7.9 | | | | |
| | P | 80 | 1.18 | 1.01 | 0.1 | 5.0 | E[3] | 2.5619 | 367.0 | 0.0108 |
| Maximum width (m) | A | 326 | 10.10 | 10.46 | 0.9 | 125.5 | | | | |
| | P | 79 | 19.77 | 15.49 | 3.0 | 91.4 | U | -5.2607 | 95.9 | 0.0001 |
| Mean depth (m) | A | 338 | 0.44 | 0.32 | 0.1 | 3.1 | | | | |
| | P | 82 | 0.70 | 0.56 | 0.2 | 4.5 | U | -3.9515 | 94.7 | 0.0001 |
| Mean width (m) | A | 338 | 8.08 | 9.60 | 0.9 | 110.0 | | | | |
| | P | 82 | 15.39 | 12.96 | 2.1 | 76.2 | U | -4.7899 | 103.5 | 0.0001 |
| Minimum width (m) | A | 327 | 5.52 | 7.91 | 0.3 | 101.1 | | | | |
| | P | 79 | 9.96 | 10.24 | 0.6 | 54.8 | U | -3.5980 | 101.6 | 0.0005 |
| Total dissolved | A | 167 | 550.16 | 569.49 | 22.0 | 4200.0 | | | | |
| solids (mg/l) | P | 43 | 299.72 | 255.18 | 34.0 | 1200.0 | U | 4.4827 | 174.5 | 0.0001 |
| Water temperature | A | 327 | 19.99 | 6.96 | 1.0 | 36.0 | | | | |
| (C) | P | 78 | 23.89 | 3.62 | 11.0 | 30.0 | U | -6.9361 | 230.3 | 0.0001 |

[1]Variance

[2]Unequal

[3]Equal

## Biomass Models

Where sample method 5 was used, only three observations contained complete data sets. Twenty-six stations were sampled using method 6. Three variables met the .5 significance level for entry into the stepwise regression model. The variables were entered into the model ($r^2$ for the model and individual variable significance levels, respectively, are in parentheses) as follows: magnesium hardness (.1551, .0225); gradient (.2611, .0827); growing season (.3351, .1231).

Complete data sets were available on 14 sites where sample method 7 was used. Only one variable, pH, was significant at the .0001 level and produced an $r^2$ of .9709 with an F statistic of 435.14. Other variables which met the .5 significance level for entry into the model were phosphates, nitrates, and turbidity. The addition of these three variables increased the model $r^2$ to .9930 but did not change the significance level of the model. All variables were significant at the .05 level with the exception of turbidity (.2313).

Only eight sites were sampled by method 4 and utilized in regression procedures. Growing season, turbidity, percent run, and phosphates were all significant variables for explaining standing crop at sites sampled by this method. No sites which were sampled by methods 1 or 8 were available for analysis for this species.

Thirteen sites were sampled by method 3. None of the variables for which curves were drawn produced significant $r^2$ values. Only five sites contained white crappie that were sampled by method 2 and, therefore, no models are available for this data. Those regression models that are available are summarized in Table 19.

Table 19. Results of stepwise multiple regression relating white crappie standing crops by collection method.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture with a final kill technique (method 6) | 26 | .33 | 3.87 | .0225 | Gradient | 3.29 | .0827 |
| | | | | | Growing season | 2.56 | .1231 |
| | | | | | Magnesium hardness | 5.99 | .0225 |
| Kill without mark and recapture (method 5) | 3 | .97 | 84.33 | .0117 | Mean width | | |
| Mark and recapture with a final kill technique combined with kill (method 5 and 6) | 31 | .45 | 4.16 | .0069 | Dissolved oxygen | 3.47 | .0742 |
| | | | | | Gradient | 4.35 | .0475 |
| | | | | | Growing season | 5.97 | .0220 |
| | | | | | Mean width | 2.13 | .1567 |
| | | | | | Magnesium hardness | 4.79 | .0382 |
| Mark and recapture seining and shocking (method 7) | 14 | .99 | 414.62 | .0001 | Nitrates | 4.97 | .0500 |
| | | | | | Phosphates | 12.28 | .0057 |
| | | | | | pH | 1557.85 | .0001 |
| | | | | | Turbidity | 1.82 | .2313 |
| Seining and shocking (method 4) | 8 | .90 | 15.45 | .0058 | Growing season | 37.58 | .0017 |
| | | | | | Turbidity | 12.33 | .0173 |
| | | | | | Percent run | 6.99 | .0458 |
| Mark and recapture seining (method 3) | 14 | .20 | 1.46 | .2741 | Secchi disc | 1.99 | .1855 |
| | | | | | Percent run | 1.30 | .2791 |
| Seining (method 2) | 5 | .98 | 141.78 | .0011 | Mean width | 235.27 | .0006 |
| | | | | | Turbidity | 21.85 | .0185 |

## Testing the Models

Using discriminant analysis and the Kansas data as a calibration data set, stream sites sampled in Oklahoma were classified into presence or absence groups for white crappie. Twenty-six sample sites of 34 where the species was not found were misclassified and placed in the presence group. Seven of nine sites where the species was found were misclassified.

Allowing a discriminant analysis to be performed on Oklahoma data, using itself for calibration and using the same variables as in the Kansas analysis, produced 17 misclassifications. Sixteen sites were placed in the presence group when sampling did not varify the species occurrence. One of 16 sites where the species did occur was placed in the absence group.

A significant Pearson correlation coefficient was found between predicted and observed standing crops of white crappie where the predicted value was computed by an equation derived from data collected by sample method 5. The coefficient value was .5191 with a significance level of .0393 ($N = 16$).

Four variables produced an $r^2$ of .31 when stepwise regression was performed to explain standing crop of white crappie based on suitability index values assigned to Oklahoma sites. The model; however, was not significant below the .05 level. Mean width alone produced an $r^2$ of .27 ($p > F = .0393$). Addition of other variables also produced non-significant models.

# CHAPTER XI

# RESULTS-GREEN SUNFISH

## Species Occurrence Model

Of 323 sites used in the analysis of green sunfish, 250 were classified correctly (77 percent). Of the 240 sites where green sunfish occurred, 89 percent were classified correctly. However, only 44 percent of 83 sites where green sunfish were absent were correctly classified. The following variables are listed in order from greatest to least importance in discriminating between presence and absence of green sunfish: water temperature, volume of flow, percent pool, minimum width, mean width, maximum width, velocity, magnesium hardness, and percent run (Table 20).

## Suitability Curves

Suitability curves were drawn for the green sunfish for the following variables: magnesium hardness, maximum width, mean depth, minimum width, pH, phosphates, turbidity, and velocity (Appendix H). Data used to prepare suitability curves are in Appendix I. Data summarizing additional variables for which curves were not drawn, are summarized in Appendix J.

Table 20. Significant relationships between presence and absence groups of green sunfish (P = presence, A = absence) for physical and chemical variables.

| Variable | Group | N | Mean | Standard deviation | Minimum value | Maximum value | V[1] | T | DF | PROB > \|T\| |
|---|---|---|---|---|---|---|---|---|---|---|
| Magnesium hardness | A | 94 | 73.80 | 65.71 | 0.0 | 440.0 | | | | |
| (mg/1) | P | 277 | 99.10 | 185.79 | 0.0 | 2530.0 | U[2] | -1.9386 | 368.4 | 0.0533 |
| Maximum width (m) | A | 104 | 15.43 | 20.09 | 0.9 | 125.5 | | | | |
| | P | 301 | 10.80 | 7.53 | 1.8 | 45.7 | U | -2.2923 | 113.1 | 0.0237 |
| Mean width (m) | A | 104 | 12.28 | 17.28 | 0.9 | 110.0 | | | | |
| | P | 316 | 8.61 | 7.22 | 1.2 | 73.1 | U | 2.0793 | 115.1 | 0.0398 |
| Minimum width (m) | A | 104 | 9.52 | 14.94 | 0.6 | 101.1 | | | | |
| | P | 302 | 5.31 | 4.28 | 0.3 | 30.4 | U | 2.8329 | 108.9 | 0.0055 |
| Pool (%) | A | 100 | 29.41 | 37.24 | 0.0 | 100.0 | | | | |
| | P | 302 | 46.94 | 40.29 | 0.0 | 100.0 | E[3] | -3.8578 | 407.0 | 0.0001 |
| Run (%) | A | 101 | 61.00 | 40.48 | 0.0 | 100.0 | | | | |
| | P | 307 | 44.27 | 42.26 | 0.0 | 100.0 | E | 3.4871 | 406.0 | 0.0005 |
| Velocity (m/sec) | A | 91 | 0.27 | 0.36 | 0.0 | 2.21 | | | | |
| | P | 286 | 0.16 | 0.43 | 0.0 | 5.70 | U | 2.5602 | 175.6 | 0.0113 |
| Volume of flow | A | 91 | 1.96 | 5.56 | 0.0 | 28.3 | | | | |
| ($m^3$/sec) | P | 286 | 0.57 | 1.84 | 0.0 | 25.1 | U | 2.3400 | 96.3 | 0.0213 |

[1]Variance

[2]Unequal

[3]Equal

## Biomass Models

Complete data sets were available from 106 sites that contained green sunfish where sampling was performed by method 6. Maximum width, velocity, and secchi disc reading were the most important variables explaining green sunfish standing crop ($r^2 = .1457$; $F = 5.86$; $p > F = .0011$). These three variables were the only ones significant at the .5 level.

Sample method 5 was used at 48 stations. Maximum width and pH produced an $r^2$ of .1407 ($p > F = .0329$) for a model involving these two variables. No significant models were produced for sample method 7 or 8. Stations which were sampled by method 1 resulted in only two complete data sets.

Fourteen sites were sampled by method 4. An $r^2$ of .5063 ($F = 5.64$; $p > F = .0206$) was obtained with phosphate and pH. Individual significance levels of the variables were, respectively, .0075 and .0962.

Thirty-seven sites were sampled by method 3. An $r^2$ of .1649 ($F = 3.36$; $p > F = .0467$) was produced by the variables secchi disc reading and maximum width. Maximum width was the only significant variable explaining green sunfish standing crop at 29 sites sampled by method 2. This one variable produced an $r^2$ of .2695 ($F = 9.96$; $p > F = .0039$). The regression models developed are summarized in Table 21.

## Testing the Models

Using discriminant analysis and the Kansas data as a calibration data set, stream sites sampled in Oklahoma were classified into presence or absence groups for green sunfish. A total of nine sites were mis-

Table 21. Results of stepwise multiple regressions relating green sunfish standing crops by collection method.

| Method of collection | N | $R^2$ | F | PROB > F | Variables | Partial F | PROB > F |
|---|---|---|---|---|---|---|---|
| Mark and recapture with a final kill technique (method 6) | 107 | .14 | 5.86 | .0011 | Secchi disc | 5.59 | .0199 |
| | | | | | Maximum width | 12.05 | .0088 |
| | | | | | Velocity | 2.26 | .1355 |
| Kill without mark and recapture (method 5) | 48 | .14 | 3.69 | .0329 | Maximum width | 3.81 | .0572 |
| | | | | | pH | 3.23 | .0782 |
| Mark and recapture with a final kill technique combined with kill stations (method 5 and 6) | 154 | .07 | 6.48 | .0020 | Maximum width | 10.15 | .0017 |
| | | | | | pH | 1.65 | .2014 |
| Mark and recapture seining and shocking (method 7) | 21 | .15 | 1.79 | .1942 | Secchi disc | 1.16 | .2955 |
| | | | | | Mean depth | 2.57 | .1252 |
| Seining and shocking (method 4) | 14 | .50 | 5.64 | .0206 | Phosphates | 10.66 | .0075 |
| | | | | | pH | 3.31 | .0962 |
| Mark and recapture shocking (method 8) | 7 | .54 | 2.37 | .2096 | Secchi disc | 4.71 | .0958 |
| | | | | | Maximum width | 2.17 | .2151 |
| Mark and recapture seining (method 3) | 37 | .16 | 3.36 | .0467 | Secchi disc | 3.03 | .0910 |
| | | | | | Maximum width | | |
| Seining (method 2) | 29 | .26 | 9.96 | .0039 | Maximum width | | |

classified. Two of three sites where green sunfish were not found were placed in the presence group. Seven of 47 sites where green sunfish were found were placed in the absence group.

A discriminant analysis, using itself for calibration, was run on the Oklahoma data using the same physical and chemical variables that were used in the Kansas stream site analysis. All three of the sites where green sunfish were not found were placed properly in the absence group. However, eight of 47 sites where the species did occur were misclassified.

Using predictive equations developed for this species from the Kansas stream survey data, no significant Pearson or Spearman correlation coefficients were obtained between predicted and observed standing crops. When suitability values were assigned each variable at each site for variables for which curves had been drawn and a stepwise regression performed on the Oklahoma data set, no significant models were developed to explain variation in standing crops of green sunfish.

## CHAPTER XII

## DISCUSSION

### Discriminant Analysis of Presence-Absence of Species

The ability to use discriminant analysis to confidently predict the probability of presence (or absence) of a species has several potential applications. One possible use would be to predict effects on fish when alterations in physical and chemical habitat characteristics have occurred. Another potential use would be in deciding whether a particular stream could support the species. For example, in deciding whether to manage for put-and-take fisheries or self-sustaining populations could be aided with such models.

The discriminant analysis on the presence or absence of spotted bass (Kansas data set) showed high reliability. Nineteen of 21 misclassifications were readily explainable (Chapter IV). However using the Kansas data set for calibration of the Oklahoma data resulted in many misclassifications. Consequently, it seems that models are potentially reliable only over limited geographical areas. Even though the Kansas data used as a calibration for Oklahoma streams showed low predictability, a discriminant analysis on the Oklahoma data set using the same variables, but with coefficients computed from the Oklahoma data set, resulted in all but one of the stream sites being correctly classified. Identical results were found for slenderhead darters (Chapter V) and similar results were obtained for orangethroat darters (Chapter VI).

These results lead to several conclusions. As geographical areas are expanded and used in analysis the possibility of encountering more variables which constrain the niche of an organism is increased. Tolerance limits for a species for a given variable may be exceeded in one area but not in another. This would result in more variables being needed to develop a model. The boundary of the geographical area to be included in a discriminant analysis model development is a function of the homogeneity of the area considered. The Kansas data set and the Oklahoma data sets could possibly be used to predict presence or absence of the species studied in their respective geographical areas.

Even lower predictability was obtained in the analysis (Kansas data set) of data on the central stoneroller (Chapter VII), and channel catfish (Chapter VIII). In addition, even more misclassifications than for the three species just referenced occurred in the discriminant analysis of Oklahoma data for largemouth bass (Chapter IX), green sunfish (Chapter XI), and white crappie (Chapter X) respectively.

In general, discriminant analysis performed solely on the Oklahoma data set produced better results than similar analysis based on the Kansas data set. This improved reliability may have been the result of less variability in how the Oklahoma data was collected. The Kansas data set was collected with a variety of sampling techniques and field crews whereas the Oklahoma data were collected with only one technique and field crew.

## Suitability Curves

Originally habitat suitability curves, prepared for the USFWS, for five of the species were drawn based on literature information relating physical and chemical variables to habitat quality (Gebhart et al. 1980). The curves developed from the Kansas data set closely approximated most of those original curves developed by Gebhart et al. (1980) for spotted bass (water temperature); green sunfish (water temperature); largemouth bass (dissolved oxygen, water temperature, turbidity, velocity); and white crappie (water temperature) (Layher and Maughan 1981). Curves developed for HEP for channel catfish by McMahon and Terrell (1982) also closely matched the Kansas curves (water temperature, turbidity, and dissolved oxygen) (Layher and Maughan 1981).

The repeatability of these curves suggests that they adequately describe habitat suitability along single axes. Theoretically, if a single habitat dimension were modified, the effect on the fish population could be predicted from the suitability curve. This simple relationship seldom occurs because a change in one variable may often be related to changes in others (Orth 1980). Orth (1982) found that the physical variables used in the formation of instream flow models did not meet the assumption of independence.

## Biomass Models

Use of equations developed from Kansas data to predict biomass in Oklahoma resulted in low biomass predictability. However, when suitability index values based on Kansas data were assigned to Oklahoma stream variables at each site, highly significant multiple regressions of standing crop on habitat variables were obtained for spotted bass ($r^2$ = .87), slenderhead darters ($r^2$ = .996), orangethroat darters ($r^2$ = .88), and central stonerollers ($r^2$ = .99). Similar regressions for largemouth bass and white crappie gave lower, but statistically significant $r^2$ values (.60 and .31, respectively). Data on green sunfish showed no significant relationships.

The variables which produced the significant models explaining species biomass differed between the Kansas and Oklahoma data sets. These differences suggest that limiting factors may vary from one stream to another and even possibly from one stream site to another within the same stream. However, the statistical analysis would suggest that much of the biomass in streams is related to abiotic factors and suitability curves developed actually reflect habitat suitability as originally suggested by the USFWS (1980,1981). Application of the curves to delineate limiting conditions for fish populations may provide a useful tool for aquatic resource managers.

In the Kansas data set, sampling technique appeared to have greatly affected standing crop predictive models. No significant regressions between habitat variables and biomass were obtained when all sites where the species occurred were utilized in the analysis. However, correlations were significant if the data set was stratified by sample method. While no criteria were developed for what sample method should be used, it appeared that mark and recapture and kill methods gave data yielding significant regression models and seining gave the least useful data.

Some variation in the complete data set may have been the result of unintentional matching of sampling technique with particular habitats. Such an approach would have divided sample sites into relatively homogeneous clusters. Such clustering may partially explain why different variables assumed importance with different sampling techniques and why different variables thus appear to be limiting to a population. The significant and often high $r^2$ values relating standing crop with a particular type of population sampling indicates a reduction in the variability, and also a reduction in the chance for more variables to be limiting.

The failure of the attempt to model the complete Kansas data set would suggest that modeling habitat suitability for large geographic areas when a variety of sampling techniques are used is impractical. However, analysis of data from a single sampling technique suggests that if data sets are reduced to represent a limited geographic area (homogeneous habitats) quantitative modeling may be accomplished.

The data also show that it is easier to model habitat suitability for those species with restricted habitat requirements. Even though these species may be found over a relatively wide geographic area, habitats may be similar enough that a reduced number of variables influence suitability. Spotted bass and slenderhead darters are examples of species with restricted habitat requirements for which the models showed relatively high reliability. Some of the other species investigated (channel catfish, white crappie, largemouth bass and green sunfish) represent fish with broader physical and chemical tolerances and models showed reduced reliability. The difference in the predictability of the models is due to the greater tolerance of these species to the number of limiting factors in aggregate than compared to species with more narrow requirements. This hypothesis needs further testing; and a way to determine overall niche breadth of species along multiple dimensions on a comparative basis is needed. Consequently, quantitatively modeling habitat suitability will produce good results for some species and poorer results for others.

This data analysis shows a new approach to developing suitability curves but no way to develop predictive models for all species. Even without predictive models, suitability curves based on quantitative data may be a strong aid in determining impacts. However since limiting factors might be expected to vary from one location to the next (as noted for species with broad niches) the best approach may be one of evaluating suitability curves for as many variables as possible and intuitively predicting the impact due to changes in all the parameters.

Another approach to predicting post-project impacts would be to collect stream data and fish population data at a number of sites on the potentially impacted stream. This restriction of area should reduce the number of limiting factors affecting the populations and allow high predictability of biomass. Factors most limiting, or at least, factors closely associated with those that are limiting, would also be identified. By using values for variables that would be expected after project completion, the effect on the fish population could be assessed. This approach would require intensive data collection for each project; however, the use of previously developed suitability curves to assign index values would greatly reduce the number of sample sites needed to develop predictive models based on empirical data (see Chapter III).

The identification of limiting factors or factors correlated with limiting factors may make species management and habitat enhancement possible on streams as well as identifying methods or concerns which can be incorporated into development projects to enhance a streams potential for supporting desirable fish populations.

## Theoretical Significance

There is some conflict between ecologists' views concerning what factors control biological populations and communities. Two schools of thought have developed from work related to community structure (Grossman, 1982).

The deterministic view basically maintains that systems are at equilibrium or are at least subject to constant, possibly gradually changing, environmental variables. Predictability of the environment intuitively suggests predictability in community structure.

Stochasticity implies random, unpredictable events control populations and community structures. Such events are unpredictable and hence, populations and community structure affected by those controls would also be unpredictable.

Tests of these conflicting hypotheses are usually based on competition or identification of limiting factors. Studies relating environmental variables to individual population levels are scarce (Layher et al. 1982) but many publications imply relationships between fish species occurrence and habitat conditions (eg. Cross 1967, Miller and Robison 1973, Pflieger 1975). For example curves have been developed to reflect associations between stream characteristics and fishes of various length groups (Orth 1980).

More literature is available relating community structure or diversity of species to environmental variables. Studies utilizing species diversity indices emphasize the importance of physical variables in reflecting community structure.

Whiteside and McNutt (1972) found diversity was inversely correlated to stream order. They attributed this negative correlation to result from spawning behavior and reactions of fish to high water. Conversely, an increase in species diversity was noted with an increase in stream order by Harrel and Dorris (1968) and Kuehne (1962). These researchers attributed increased diversity to decreased environmental fluctuations and increased available habitat in larger ordered streams. Several studies have correlated diversity with single physical factors. Sheldon (1967) found depth of a stream was correlated to the number of species present and Tramer and Rodgers (1973) stated within station diversity was dependent on local conditions of substrate and water quality. Harrel et al. (1967) noted species diversity was correlated with gradient as well as stream order. Stream velocity has also been found to control the presence of certain species (Jenkins and Freeman 1972). Matthews et al. (1982) speculated that the range of <u>Etheostoma spectabile</u>, in streams of the Great Plains, may be limited by turbidity as well as the exceedence of the thermal tollerance of the species. Rose and Echelle (1981) found that certain fish species associations were highly correlated to specific habitat types as determined by 14 variables. Deterministic regulation of other stream fish populations and even intertidal pools has also been suggested (Adams and Oliver 1977, Werner 1977, Gatz 1979, Werner and Hall 1979, Grossman 1982).

Under severe repetitive environmental perturbations, predictability may still develop. Pianka (1980) has shown such data for desert lizard communities and Binns and Eiserman (1979) have developed predictive models for trout standing crops in Wyoming streams.

Biological responses of fish to environmental variables can also affect diversity values at stream sites. Betchel and Copeland (1970) found that low species diversity values were the result of life history phenomena. Factors such as spawning behavior triggered by high flows are an example of these types of factors (Whiteside and McNutt 1972).

The evidence that random events control fish populations is more recent than the environmental control hypothesis. In a study of an Indiana stream fish assemblage Grossman et al. (1982) concluded that stochastic forces appear to be the most likely mechanism influencing structural and functional relationships. Even though a significant correlation among ranks of dominant species occurred in summer months, the possibilities of deterministic controls were disregarded. In Grossman et al's. (1982) study, environmental variables were not mentioned and were assumed to be stable. Water quality changes were apparently not monitored but have been found to influence populations and diversity of some fishes (Tramer and Rodgers 1973). Matthews (1982) found fish community structure in Ozark streams to be no more structured than could result from random distributions of the species studied.

Wiens (1977) presented a concept of community control which is mechanistically intermediate between determinism and stochasticity (Grossman et al. 1982). According to this idea, competition (a major deterministic mechanism) occurs during bottlenecks or competitive crunches; but, most of the time, resources are not limited, expansion of species ecological function(s) occurs, and stochastic control predominates.

Some recent work has shown a modified deterministic control of stream fish populations. Orth (1980) found significant correlations between some fish species standing crops and the amount of area inhabitable as determined by multiplying area available by suitability curve values for specific habitat variables (weighted usable area concept). These correlations were significant only for summer months during low flow conditions in a southeastern Oklahoma stream. Based on these and other data Orth and Maughan (1980) and Jones and Maughan (1980) suggested that repetitive abiotic factors such as summer low flows control fish populations in streams of southeastern Oklahoma.

Positive relationships between species standing crop and environmental variables found in this study indicate that some fish populations are predictable. High and statistically significant $r^2$ values were found to exist between standing crops and both physical and chemical variables in Kansas and Oklahoma prairie streams. However, not all $r^2$ values were significant nor were all species equally predictable. At least some of the variation in the data could have been imposed by procedures used in this study. Data collected in Kansas were predominately summer time (1974-1977) data and Oklahoma collections were made between June and August (1981), inclusive. In spite of seasonal and location differences, much of the variation in standing crops in Oklahoma streams was explained by the habitat suitability curves derived from Kansas data. However, stepwise multiple regressions revealed that variables important in explaining Kansas standing crops for an individaul fish species were not the same as those for the same species in Oklahoma streams. Indexing of each physical and chemical variable for each species at each stream site in both Kansas and Oklahoma precluded the comparison of variable weights in predictive equations to evaluate importance as different scales were used for each variable. It would not appear logical to expect that the same variables were limiting stream fish populations in Kansas as in Oklahoma but it would seem plausible to expect regression equations to predict standing crops for the area for which they were developed. The fact that summertime conditions (environmental variables) do explain much variation in standing crops in this study suggests that deterministic mechanisms are operating on fish populations in prairie streams via repetitive abiotic factors. As previously noted, this interpretation fits better for some species than for others. Biomass of species with broad tolerances for environmental conditions (notably green sunfish) might be expected to show lower biomass predictability than species with more limited tolerance.

It is apparent that unpredictable climatic events (stochastic control) can influence fish populations. For example, Layher (1981) found that the summertime standing crop biomass of spotted bass was highly correlated with springtime flow conditions of the year. When springtime flows were high spotted bass biomass was high. When flow conditions were high in the spring two or three years before fish sampling occurred, spotted bass biomass was negatively correlated and significant when related to those flows, possibly indicating a loss of nest sites and consequently, a loss of recruitment of young fish. Another case of stochastic control was described by Brunson (1978); many small streams in central and eastern Kansas had 50-100 percent winter kills of fishes in 1977 due to prolonged ice and snow cover combined with unusually low flows and resulting oxygen depletion. However, these stochastic events appear to be localized and superimposed on a generally deterministic control.

It appears from the results of this study that summertime fish populations can generally be explained by environmental variables associated with low flow. A review of data for many Kansas streams (Jordan 1978, 1979) indicates that low flow conditions occur on most streams in late summer. As previously indicated, Orth (1980) found correlations between weighted useable area and fish biomass for several species during low flow conditions in southeastern Oklahoma streams. The timing of this low flow condition is predictable and may represent a bottleneck to fish populations in prairie streams.

The severity of the perturbation, however, is largely unpredictable in terms of how long the duration lasts and may be more severe in some years than others. Consequently during summers with exceptionally high flows, populations may not be as severely impacted as during those with very low flows.

Intuitively, several generalizations regarding populations and perturbations can thus be formulated. Recovery from severe perturbations is a function of the species' individual longevity, reproductive potential, and optimality of habitat conditions following the perturbation. The length of time of a severe perturbation determines the impact of that perturbation. This latter factor (data from Kansas was collected over a period of five years) may well account for much of the variation in standing crops seen in habitat suitability curve development in this study.

The probability of biological competition or resource partitioning is directly related to the length of both optimal conditions and severe perturbations.

Low flow events occur almost yearly in prairie streams and represent a time of limiting conditions. Normally, conditions during seasons other than summer are time of resource abundance in relation to existing populations, however, random events can influence populations during those times.

Because of the variability of populations and the variability of perturbations on systems it is probable that precise biomass models will never be acheived. This lack of precise models however, does not mean that trends in relations between populations and environmental variables cannot be established. Habitat suitability curves developed in this study for summertime fish populations provide a useful tool for environmental resource managers who must make daily decisions with regard to potential impacts on stream fish populations.

# CHAPTER XIII

## SUMMARY AND CONCLUSIONS

Variables useful in predicting presence and absence of individual species differed between Kansas streams and Oklahoma streams. Consequently, it appears that these predictive models are not applicable over a wide geographic area. However, the suitability curves developed in both aspects of this study were very similar and appear reliable. The limits depicted on the suitability curves generally defined optimal ranges correctly. Based on these data suitability curves are useful in identifying limiting factors or those closely associated with limiting factors.

Variables useful in predicting biomass or standing crops were also different between Kansas and Oklahoma streams. However the data from Kansas and Oklahoma indicated that by sampling a number of stream segments within a project area and assigning index values for each variable for a given species, to each site, stepwise regression analysis could be used to explain much of the variation in a species standing crop. Based on these results, care should be exercised in using models developed for one area to predict changes in populations in other areas. This care is necessary because different variables may be limiting to an individual species from one stream to another.

In evaluating project impacts, a resource manager must priortize the species. Changes in physical or chemical attributes of streams may cause a decrease in one population but an increase in another. Addressing changes in habitat quality is meaningless unless one determines what changes constitute unacceptable levels of changes to the environment.

It is quite possible that curves or models developed herein could be misused if the limitations were not understood. Our methods use only a relatively few variables to assess presence or absence and biomass. Failure of these models should sometimes be expected because factors limiting at one site or region may not be those which are limiting at another. In other words, if a model does not contain those factors which limit a population (or factors closely associated with limiting factors) predictability cannot be accomplished. In addition, a modification can cause a factor which was not included in model development to become limiting. This sequence of events would again lead to model failure.

## LITERATURE CITED


Adams, G. F., and C. H. Oliver. 1977. Yield properties and structure of boreal percid communities in Ontario. Journal of the Fisheries Board of Canada 34:1613-1625.

Bain, M. B., J. T. Finn, L. J. Gerardi, Jr., M. R. Ross, and W. P. Saunders, Jr. 1982. An evaluation of methodologies for assessing the effects of flow fluctuations on stream fish. Massachusetts Cooperative Fishery Research Unit, Project Completion Report, Contract USDI 14-16-0009-80-1003, Amerst, Massachussetts, USA.

Betchel, T. J., and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Cont. Marine Science 15:103-132.

Blair, A. P. 1959. Distribution of the darters (Percidae, Etheastomatinae) of northeastern Oklahoma. The Southwestern Naturalist 4:1-13.

Blair, W. H. 1979. SAS user's guide. SAS Institute, Inc., P.O. Box 10066, Raleigh, North Carolina 27605, USA.

Blair, W. F., and T. H. Hubbell. 1938. The biotic districts of Oklahoma. The American Midland Naturalist 20:425-454.

Binns, N. A., and F. E. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108:215-228.

Bovee, K. D., and T. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments: Fisheries. United States Fish and Wildlife Service, Instream Flow Information Paper 3, FWS/OBS-77/63, Fort Collins, Colorado, USA.

Boyd, C. E. 1976. Evaluation of a water analysis kit. Agricultural Experiment Station, Auburn University, Auburn, Alabama, Leaflet 92:1-3.

Boyd, C. E. 1977. Evaluation of a water analysis kit. Journal of Environmental Quality 6:381-384.

Boyd, C. E. 1980. Reliability of water analysis kits. Transactions of the American Fisheries Society 109:239-243.

Brunson, K. 1978. Personal communications Stream Investigator, Kansas Fish and Game Commission, Pratt, Kansas, USA.

Carle, F. L., and O. E. Maughan. 1980. Accurate and efficient estimation of benthic populations: A comparison of removal estimation and conventional sampling techniques. Hydrobiologia 70:181-182.

Carle, F. L., and M. R. Strubb. 1978. A new method for estimating population size from removal data. Biometrics 34:621-630.

Chapman, D. W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in Western Washington. Transactions of the American Fisheries Society 109:357-363.

Cross, F. B. 1967. Handbook of the fishes of Kansas. University of Kansas, Museum of Natural History Miscellaneous Publication 45:1-357.

Cross, F. B. 1970. Fishes as indicators of Pleistocene and recent environments in the Central Plains. Pages 241-257 in W. Dort, Jr., and J. K. Jones, Jr., editors. Pleistocene and recent environments of the Central Great Plains, Special Publications 3. Department of Geology, University of Kansas, Lawrence, Kansas, USA.

Fritz, E. S. 1980. Potential impacts of low pH on fish and fish populations. United States Fish and Wildlife Service, Biological Services Program, National Power Plant Team, FWS/OBS-80/40.2, Ann Arbor, Michigan, USA.

Gatz, J. 1979. Community organization in fishes as indicated by morphological features. Ecology 60:711-718.

Gebhart, G., O. E. Maughan, and M. Bacteller. 1980. Preliminary draft reports on habitats of various centrachids. Oklahoma Cooperative Fisheries Research Unit, Oklahoma State University, Stillwater, Oklahoma, USA.

Green, R. H. 1971. A multivariate statistical approach to the Hutchinsonian niche: Bivalve molluses of Central Canada. Ecology 52:543-556.

Grossman, G. D. 1982. Dynamics and organization of a rocky intertidal fish assemblage: the persistence and resilience of taxocene structure. The American Naturalist 119:611-637.

Grossman, G. D., P. B. Moyle, and J. O. Whitaker, Jr. 1982. Stochasticity in structural and functional characteristics of an Indiana stream fish assemblage: a test of community theory. The American Naturalist 120:423-454.

Hambridge, G., and M. J. Drown. 1941. Climate and man, yearbook of agriculture. United States Department of Agriculture, Washington, District of Columbia, USA.

Harrel, R. C., B. J. Davis, and T. C. Dorris. 1967. Stream order and species diversity of fishes in an intermittent Oklahoma stream. The American Midland Naturalist 73:428-436.

Harrel, R. C., and T. C. Dorris. 1968. Stream order, morphometry, physio-chemical conditions, and community structure of benthic macroinvertebrates in an intermittent stream system. The American Midland Naturalist 80:220-251.

Hirsch, A. 1978. Environmental impact assessment: Its role in protecting fish and wildlife values. Pages 23-29 in S. H. Smith, and A. H. Rosenthal, editors. Concepts and practices in Fish and Wildlife administration. United States Fish and Wildlife Service, Department of the Interior, Washington, District of Columbia, USA.

Hulen, P. L., and E. E. Angino. 1979. Nitrate and phosphate; time-trend concentrations in selected Kansas streams. Transactions of the Kansas Academy of Science 82:73-83.

Hutchinson, G. E. 1957. Concluding Remarks. Cold Spring Harbor Symposium on Quantitative Biology 22:415-427.

Jenkins, R. E., and C. A. Freeman. 1972. Longitudinal distribution and habitat of the fishes of Mason Creek, an upper Roanoke River drainage tributary, Va. Virginia Journal of Science 23:43-202.

Jones, R. N. 1981. The community structure and interrelationships among darters (Percidae) in Glover Creek, Oklahoma, USA. Master's thesis, Oklahoma State University, Stillwater, Oklahoma, USA.

Jones, R. N., and O. E. Maughan. 1980. Some aspects of the biology and ecology of the leopard darter, Percina pantherina: Status of populations in Glover Creek, McCurtain County, Oklahoma. United States Fish and Wildlife Service, PN82220-0005, Albequerque, New Mexico, USA.

Jordan, P. R. 1978. Statistical summary of streamflow data for Kansas streams in the Arkansas River Basin. Water Resources Board. Technical Report No. 14A. 206pp.

Jordan, P. R. 1979. Statistical summary of streamflow data for Kansas streams in the Missouri River Basin. Water Resources Board. Technical Report No. 14B. 334pp.

Kuehne, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecology 43:608-614.

Layher, W. G. 1981. Unpublished data. Oklahoma Cooperative Fishery Research Unit, Stillwater, Oklahoma, USA.

Layher, W. G., and O. E. Maughan. 1981. Analysis and refinement of habitat evaluation procedures for eight warm-water fish species. Oklahoma Cooperative Fishery Research Unit, Project Completion Report, Stillwater, Oklahoma, USA.

Layher, W. G., O. E. Maughan, and W. D. Warde. 1982. Utilizing the SAS computer system for modeling habitat suitability for warmwater fishes in streams. Pages 355-361 in N. B. Armantrout, editor of a symposium: acquisition and utilization of aquatic habitat inventory information, Portland, Oregon. Western Division of the American Fisheries Society.

Layher, W. G., R. Standage, and K. Brunson. 1978. Assessment of the aquatic environment in Kansas. Kansas Department of Health and Environment, Report TR-11.1, Topeka, Kansas, USA.

Lessenden, G. A. 1976. Analysis of habitats and fish distribution in Neosho and Verdigris drainage basins of Kansas. M. A. thesis, University of Kansas, Lawrence, Kansas, USA.

Lockard, F. R. 1979. Cooperation in action - the central states pond management work group. Pages 4-5 in G. P. Novinger, and J. G. Dillard, editors. New approaches to the management of small impoundments. North Central Division, American Fisheries Society Special Publication Number 5.

Marking, L. L., and T. D. Bills. 1976. Toxicity of rotenone to fish in standardized laboratory tests. Investigations in fish control. 72. Fish Control Laboratories, United States Fish and Wildlife Service, La Crosse, Wisconsin, USA.

Matthews, W. J. 1982. Small fish community structure in Ozark streams: structured assembly patterns or random abundance of species? The American Midland Naturalist 107:42-54.

Matthews, W. J., E. Surat, and L. G. Hill. 1982. Heat death of the orangethroat darter Etheostoma spectabile (Percidae) in a natural environment. The Southwestern Naturalist 27:216-217.

McMahon, T. E., and J. W. Terrell. 1982. Habitat suitability index models: channel catfish. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.2, Ft. Collins, Colorado, USA. 29pp.

Milhous, R. T., D. L. Wegner, and T. Waddle. 1981. Users guide to physical habitat simulation system. United States Fish and Wildlife Service, Instream Flow Information Paper 11, FWS/OBS-81/43, Fort Collins, Colorado, USA.

Miller, R. J., and H. W. Robison, 1973. The fishes of Oklahoma. Oklahoma State University Press, Stillwater, Oklahoma, USA.

Nelson, K. L., and E. Weaver. 1981. Criteria for the design and evaluation of stream excavation projects in North Carolina. Fisheries 6:7-10.

Oklahoma State University. 1979. Oklahoma in maps. Cartography service, Department of Geography, Oklahoma State University, Stillwater, Oklahoma, USA.

Orth, D. J. 1980. Evaluation of a methodology for recommending instream flows for fishes. Doctoral thesis, Oklahoma State University, Stillwater, Oklahoma, USA.

Orth, D. J., and O. E. Maughan. 1980. Instream flow methodology evaluation and flow quantification for Oklahoma streams. Oklahoma Cooperative Fishery Research Unit, Phase II Project Completion Report, Stillwater, Oklahoma, USA.

Patten, B. C., et al. 1979. Module III: Instream fishery ecosystems. Pages 139-166 in G. L. Smith, editor. Proceedings, workshop in instream flow habitat criteria and modeling. Information Series 40, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, USA.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri, USA.

Pianka, E. R. 1978. Evolutionary Ecology. Harper and Row, Publishers, New York, New York, USA.

Pianka, E. R. 1980. Guild structure in lizards. Seminar at Oklahoma State University. October 24.

Platts, W. S. 1980. A plea for fishery habitat classification. Fisheries 5:2-6.

Project Evaluation Team. 1979. Habitat evaluation procedures (draft). Division of Ecological Services, United States Fish and Wildlife Service, Fort Collins, Colorado, USA.

Raleigh, R. F. 1978. Habitat evaluation procedures for aquatic assessments. Pages 131-157 in W. T. Mason, Jr., editor. Methods for the assessment and prediction of mineral mining impacts on aquatic communities: a review and analysis. Eastern Energy and Land Use Group, Harpers Ferry, West Virginia, USA.

Raleigh, R. F., and C. Short. 1981. Depletion sampling in stream ecosystems: assumptions and techniques. The Progressive Fish Culturist 43:115-120.

Rose, D. R., and A. A. Echelle. 1981. Factor analysis of associations of fishes in Little River, Central Texas, with an interdrainage comparison. The American Midland Naturalist 106:379-391.

Samuels, W. B., A. Uzzo, and R. Nuzzi. 1979. Correlations of phytoplankton standing crop, species diversity and dominance with physical-chemical data in a coastal salt pond. Hydrobiologia 64:233-238.

Sheldon, A. L. 1967. Species diversity and longitudinal succession in stream fishes. Ecology 49:193-198.

Smith, G. R., and D. R. Fisher. 1970. Factor analysis of distribution patterns of Kansas fishes. Pages 259-277 in W. Dort, Jr., and J. K. Jones, Jr., editors. Pleistocene and recent environments of the Central Great Plains, Special Publication 3. Department of Geology, University of Kansas, Lawrence, Kansas, USA.

Strickland, J., and T. R. Parsons. 1968. A practical handbook of sea water analysis. Fisheries Research Board of Canada, Bullentin 167.

Tramer, E. J., and P. M. Rodgers. 1973. Diversity and longitudinal zonation in fish populations of two streams entering a metropolitan area. The American Midland Naturalist 90:366-374.

United States Fish and Wildlife Service. 1979. Assessing impacts of development on fish and wildlife. The Bulletin, Habitat Preservation News 3:1-3.

United States Fish and Wildlife Service. 1980. Habitat as a basis for environmental assessment, 101 ESM. Division of Ecological Services, Department of the Interior, Washington, District of Columbia, USA.

United States Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models, 103 ESM. Division of Ecological Services, Department of the Interior, Washington, District of Columbia, USA.

Waters, B. F. 1976. A methodology for evaluating the effects of different stream flows on salmonid habitat. Pages 245-246 in J. F. Orsborn, and C. H. Allman, editors. Instream flow needs, proceedings of the symposium and speciality conference, volume 2. American Fisheries Society, Bethesda, Maryland, USA.

Wehnes, R. E. 1982. Personal communications. Missouri Department of Conservation, Jefferson City, Missouri, USA.

Werner, E. 1977. Species packing and niche complementarity in three sunfishes. The American Naturalist 111:553-578.

Werner, E., and D. J. Hall. 1979. Foraging efficiency and habitat switching in competing sunfishes. Ecology 60:256-264.

Whiteside, B. G., and R. M. McNutt. 1972. Fish species diversity in relation to stream order and physiochemical conditions in the Plum Creek drainage basin. The American Naturalist 88:90-101.

Wiens, J. A. 1977. On competition and variable environments. The American Scientist 65:590-597.

Winger, P. V. 1981. Physical and chemical characteristics of warmwater streams: a review. American Fisheries Society, Warmwater Streams Symposium 1981:32-44.

Wood, R. 1982. Personal communications Kansas Fish and Game Commission, Pratt, Kansas, USA.

APPENDICES

# APPENDIX A

## SPOTTED BASS SUITABILITY CURVES (INTERVAL RANGES, MEANS, AND N VALUES GIVEN IN APPENDIX I)

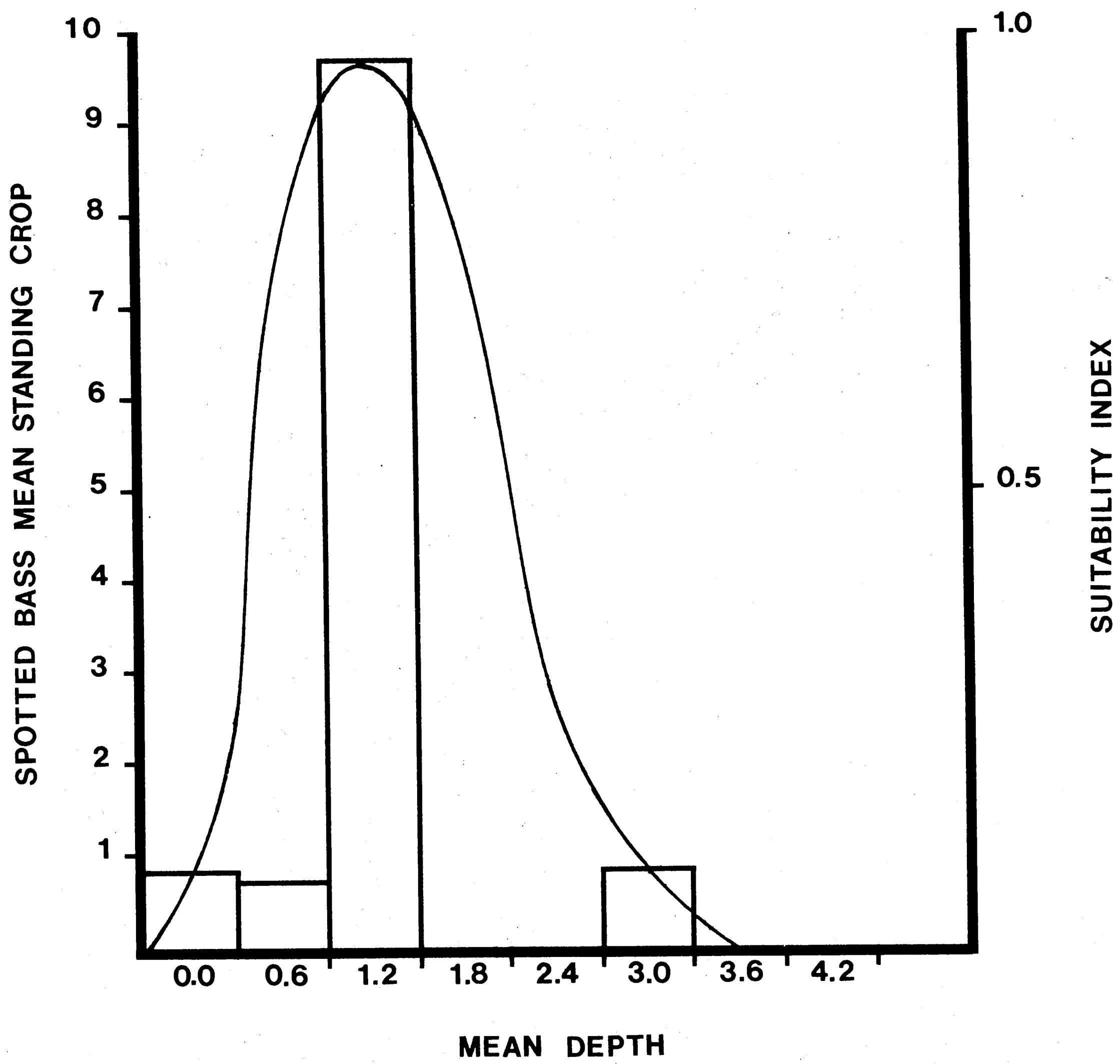


Figure 7. Relationship between spotted bass mean standing crop kg/ha) and mean stream depth (m).

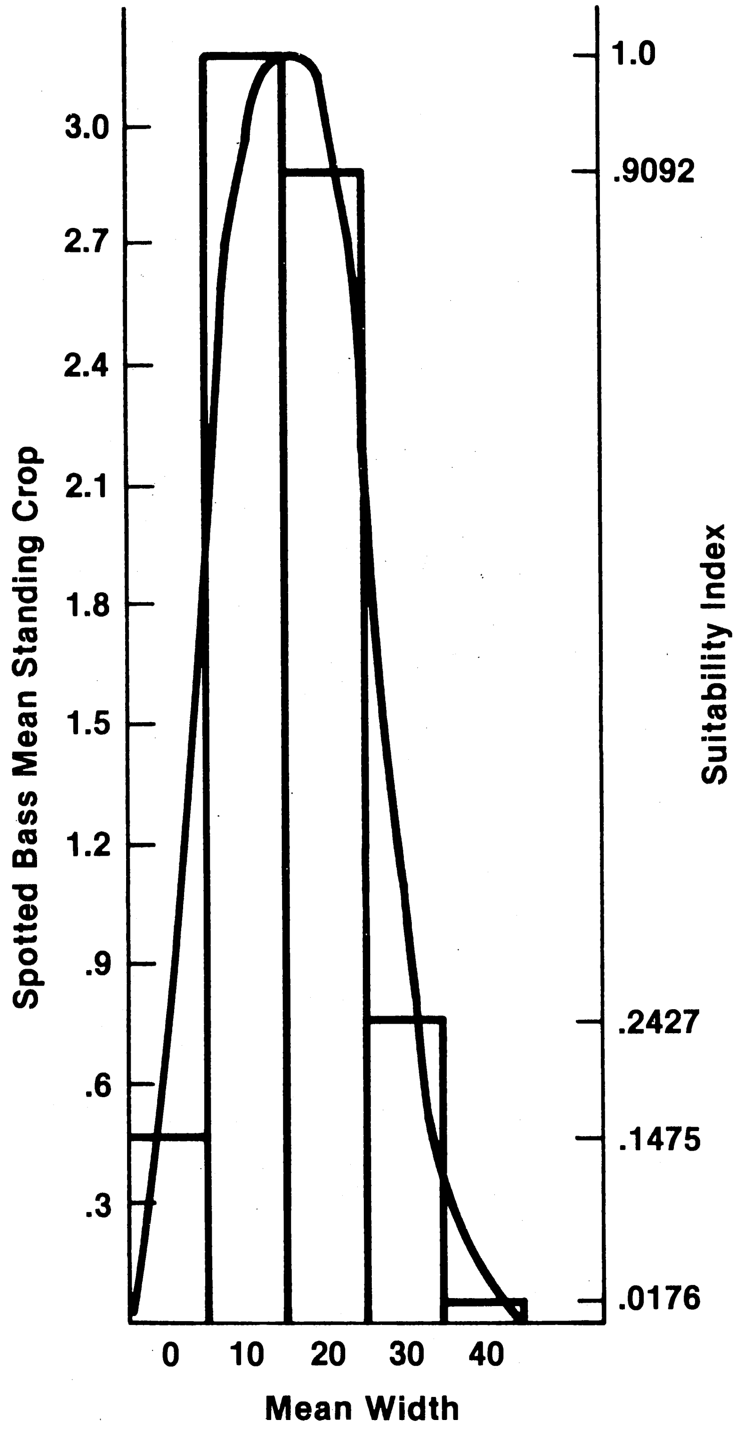


Figure 8. Relationship between spotted bass mean standing crop (kg/ha) and mean stream width (m).

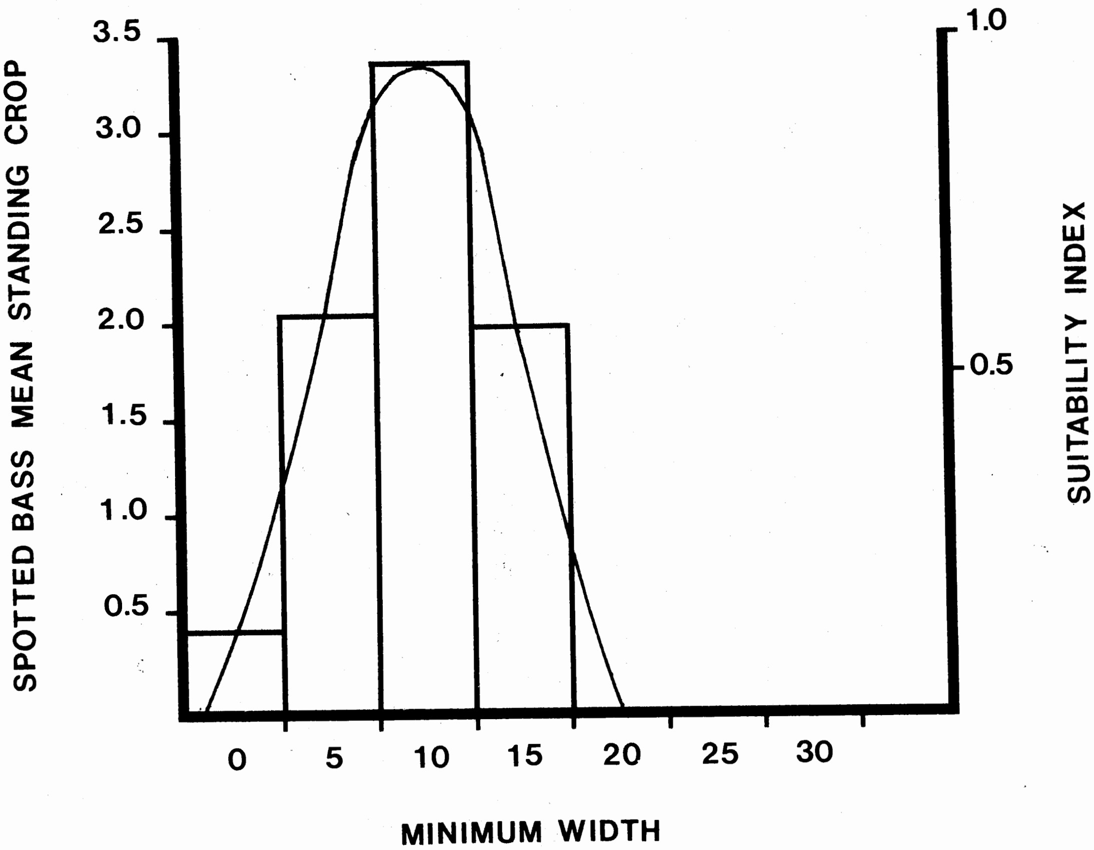


Figure 9. Relationship between spotted bass mean standing crop (kg/ha) and minimum stream width (m).

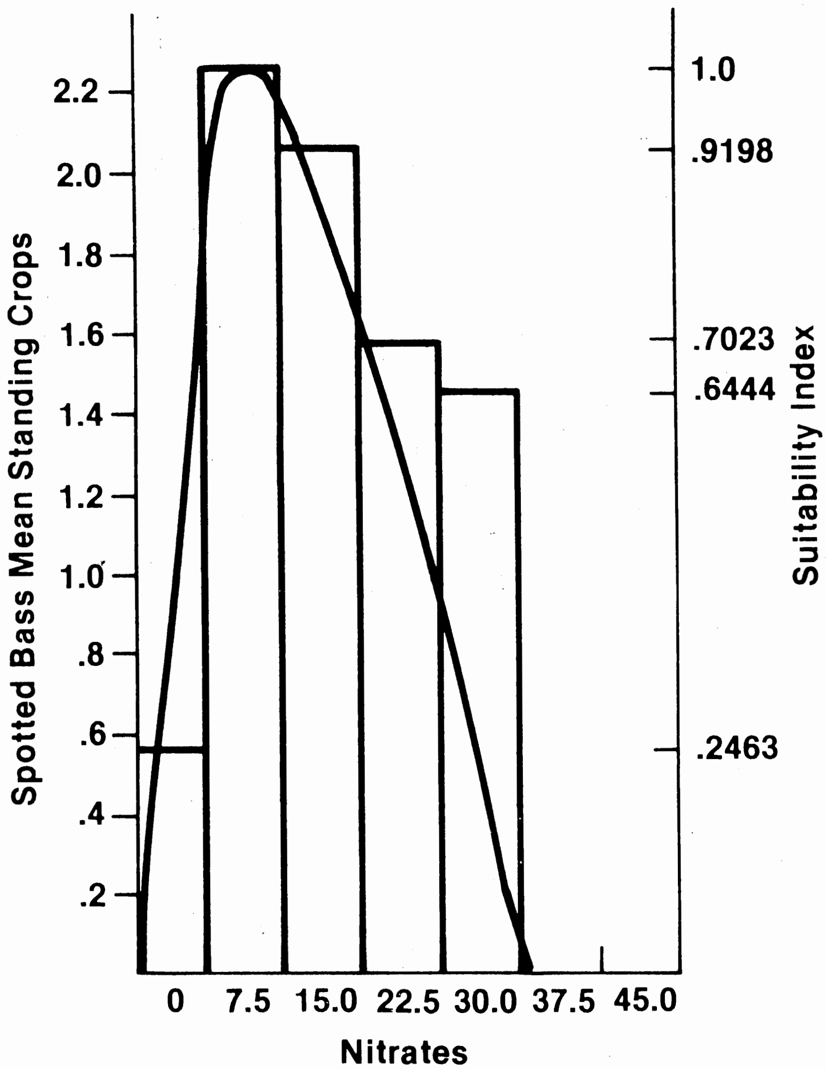


Figure 10. Relationship between spotted bass mean standing crop (kg/ha) and nitrates (mg/l).

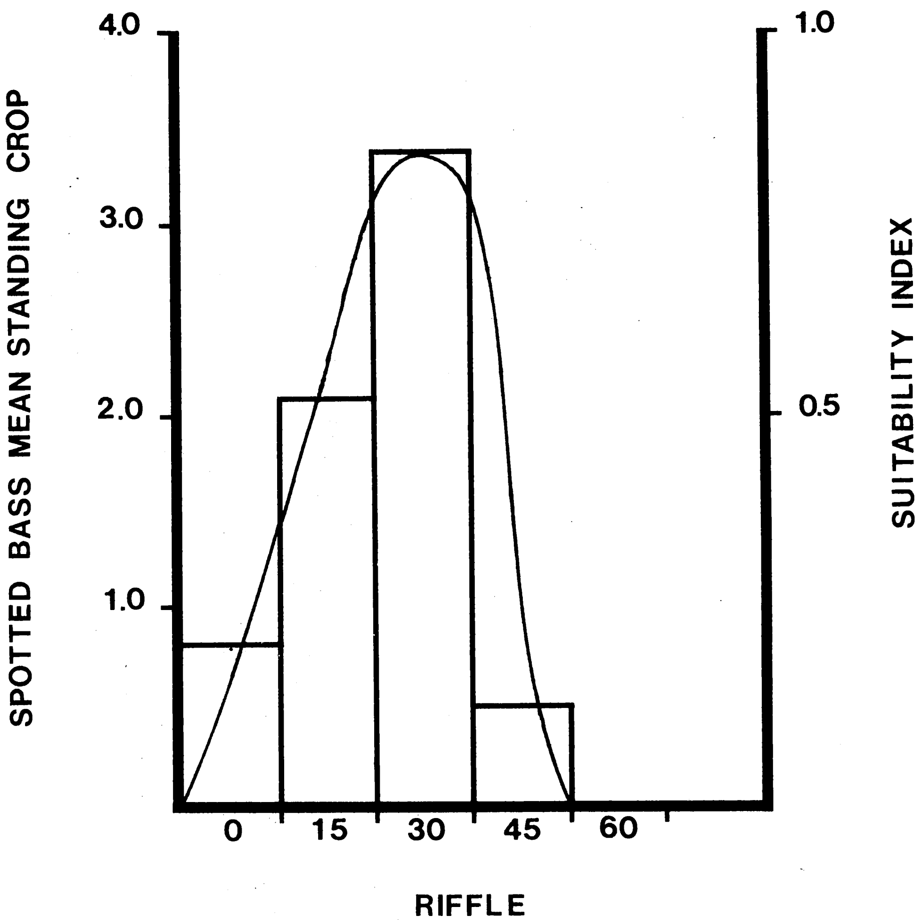


Figure 11. Relationship between spotted bass mean standing crop (kg/ha) and percent riffle.

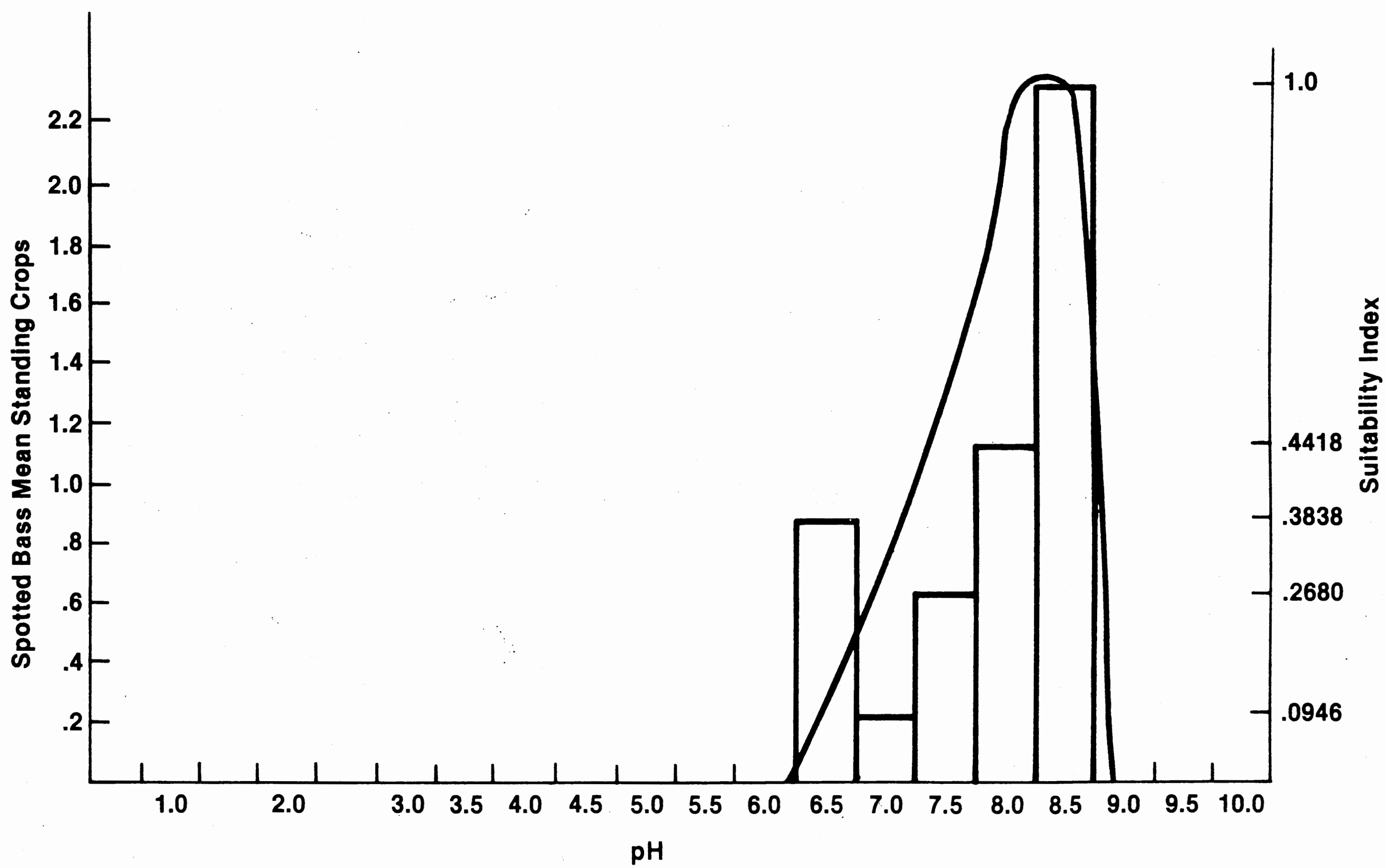


Figure 12. Relationship between spotted bass mean standing crop (kg/ha) and pH.

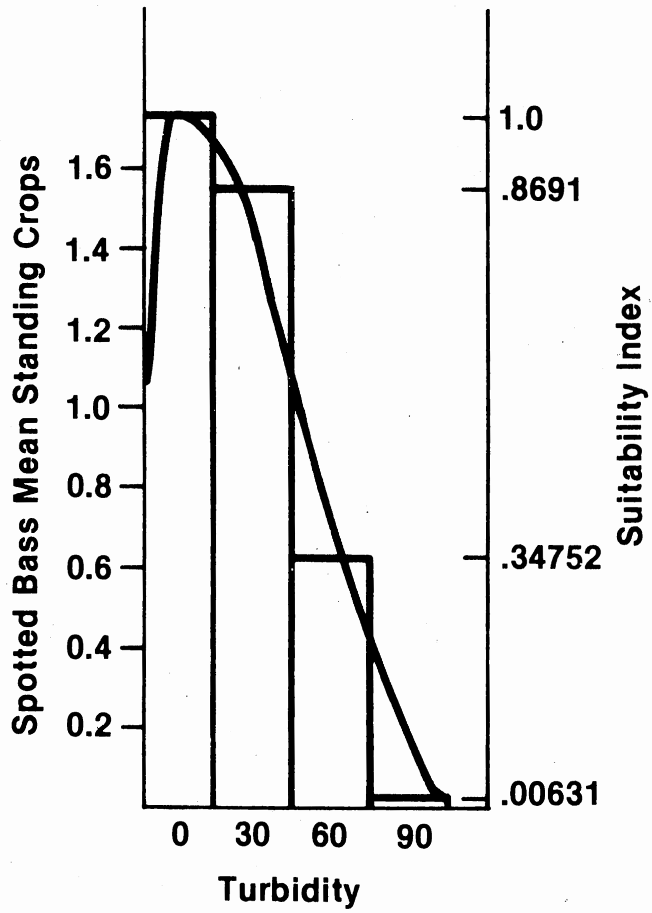


Figure 13. Relationship between spotted bass mean standing crop (kg/ha) and turbidity (JTU's).

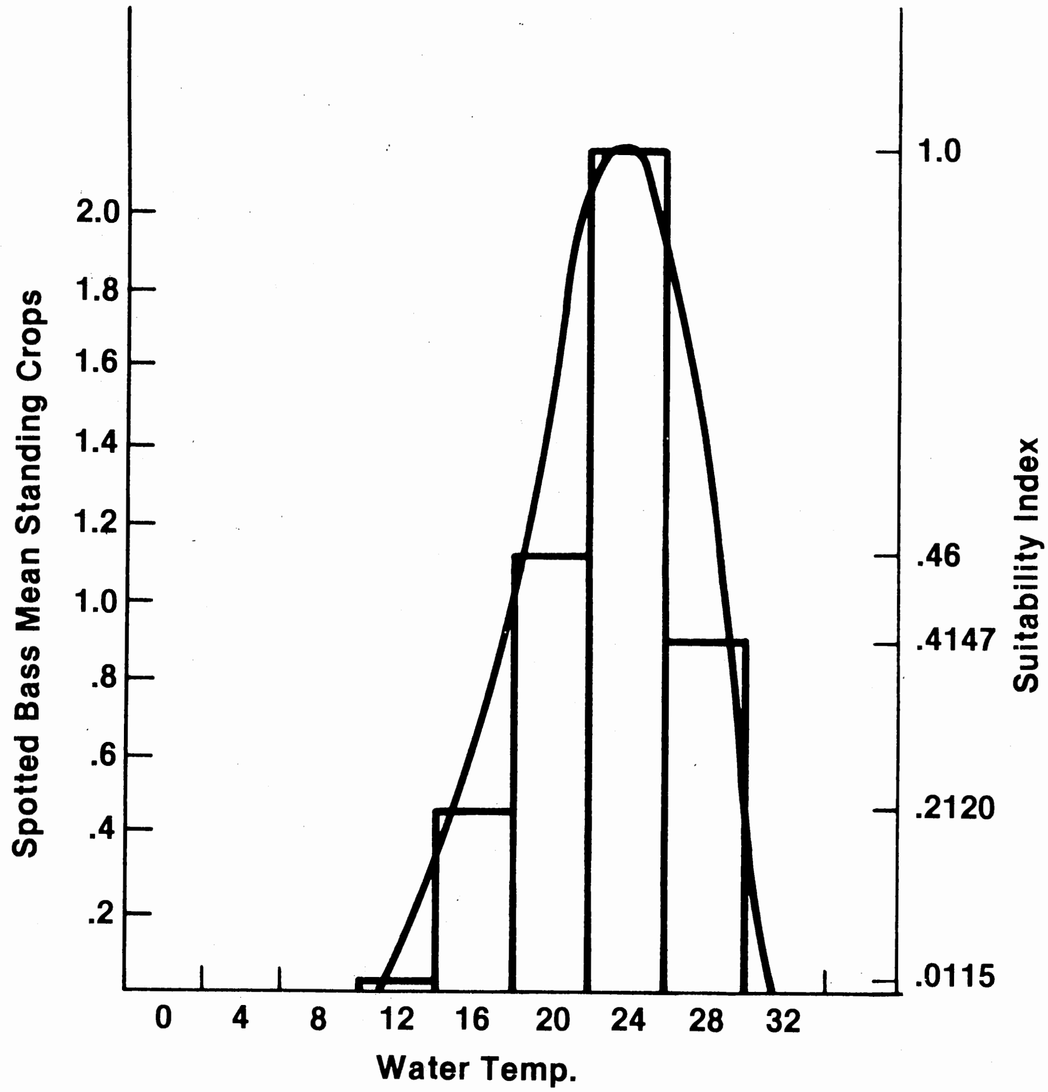


Figure 14. Relationship between spotted bass mean standing crop (kg/ha) and water temperature (C).

APPENDIX B

SLENDERHEAD DARTER SUITABILITY CURVES

(INTERVAL RANGES, MEANS, AND N VALUES

GIVEN IN APPENDIX I)

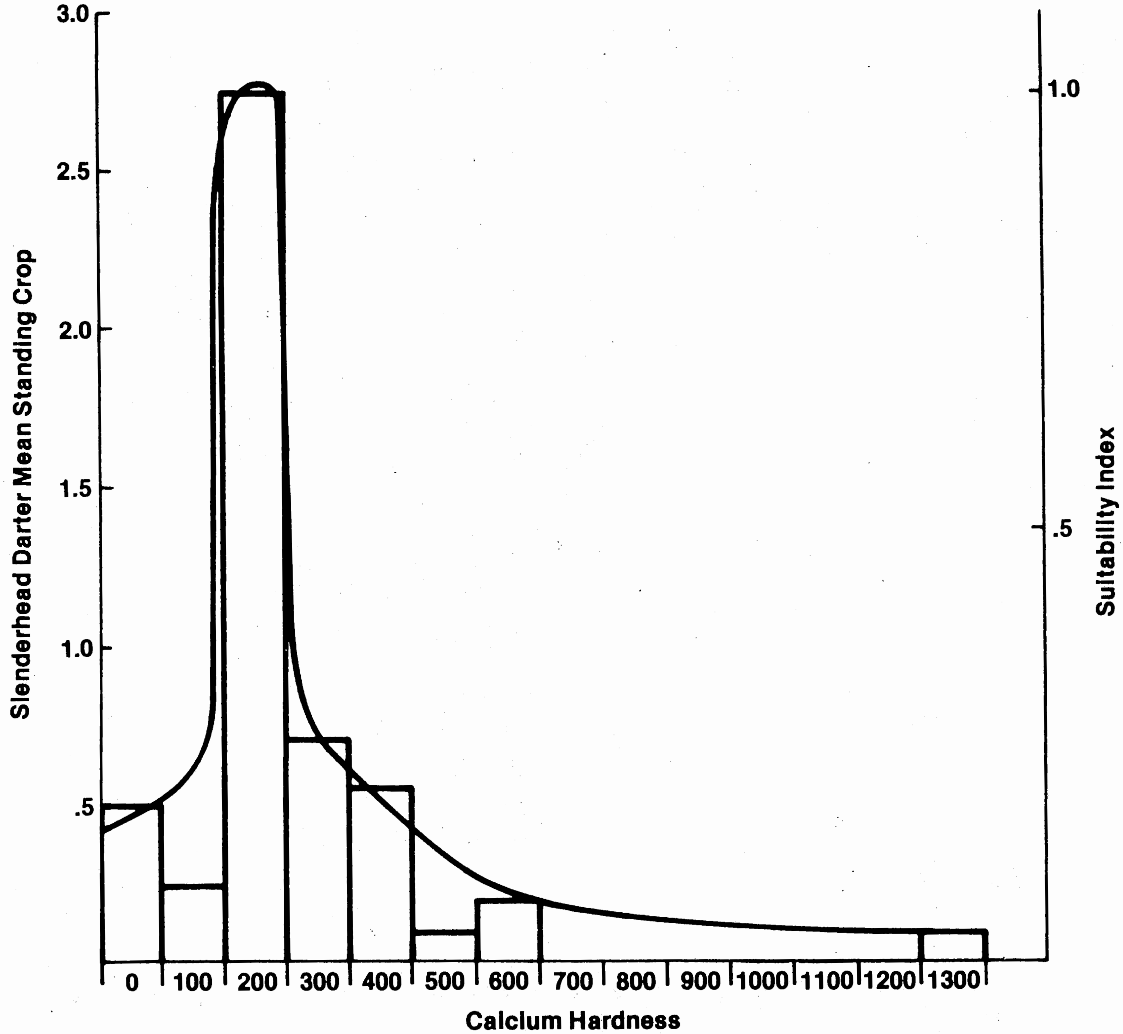


Figure 15. Relationship between slenderhead darter mean standing crop (kg/ha) and calcium hardness (mg/l).

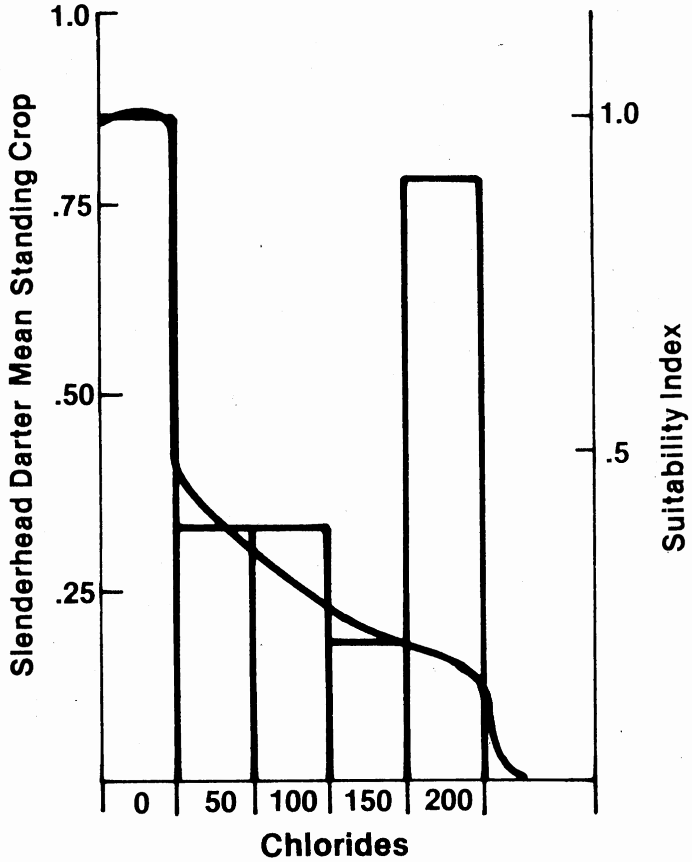


Figure 16. Relationship between slenderhead darter mean standing crop (kg/ha) and chlorides (mg/l).

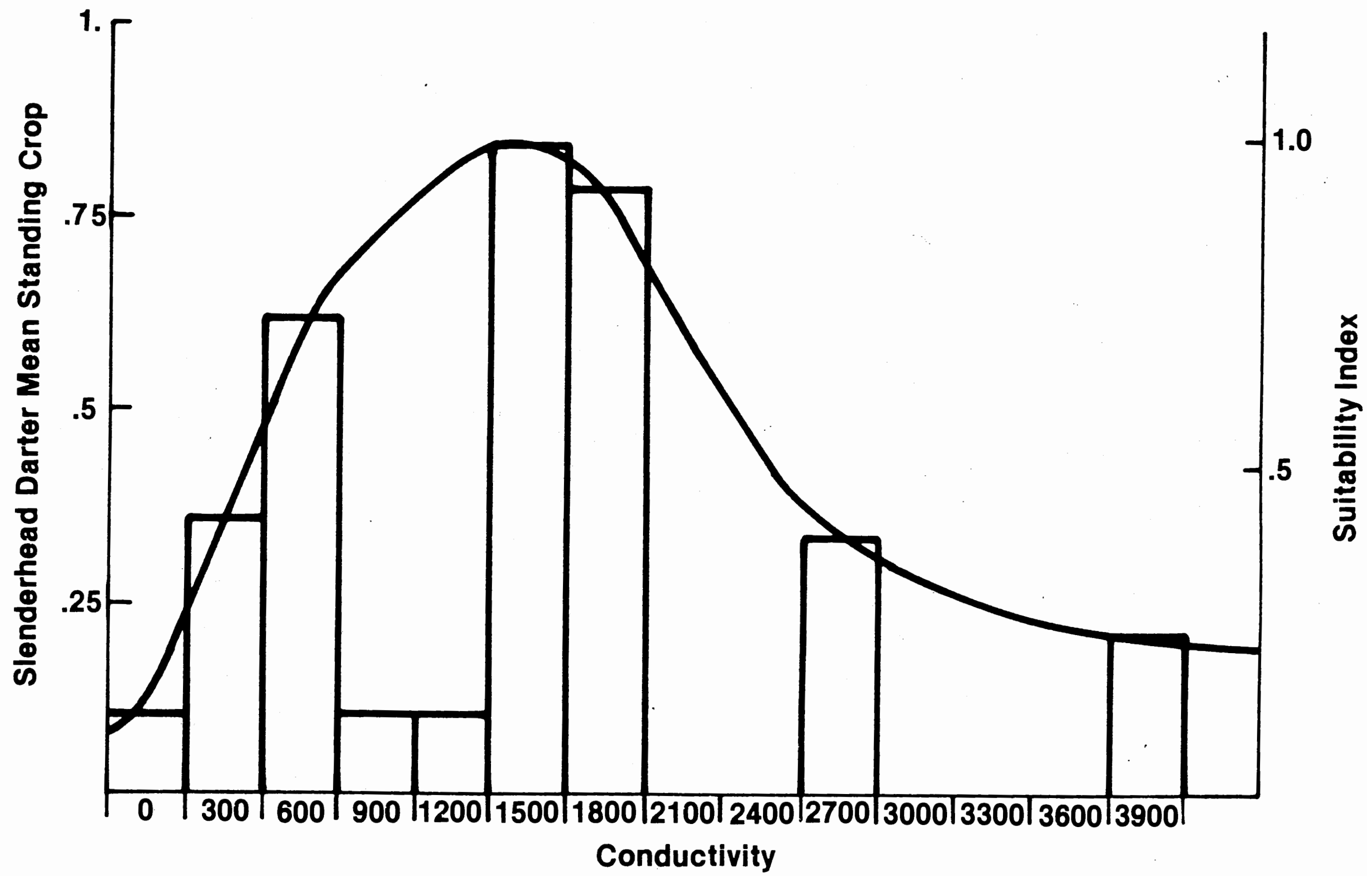


Figure 17. Relationship between slenderhead darter mean standing crop (kg/ha) and conductivity (μmhos/cm).

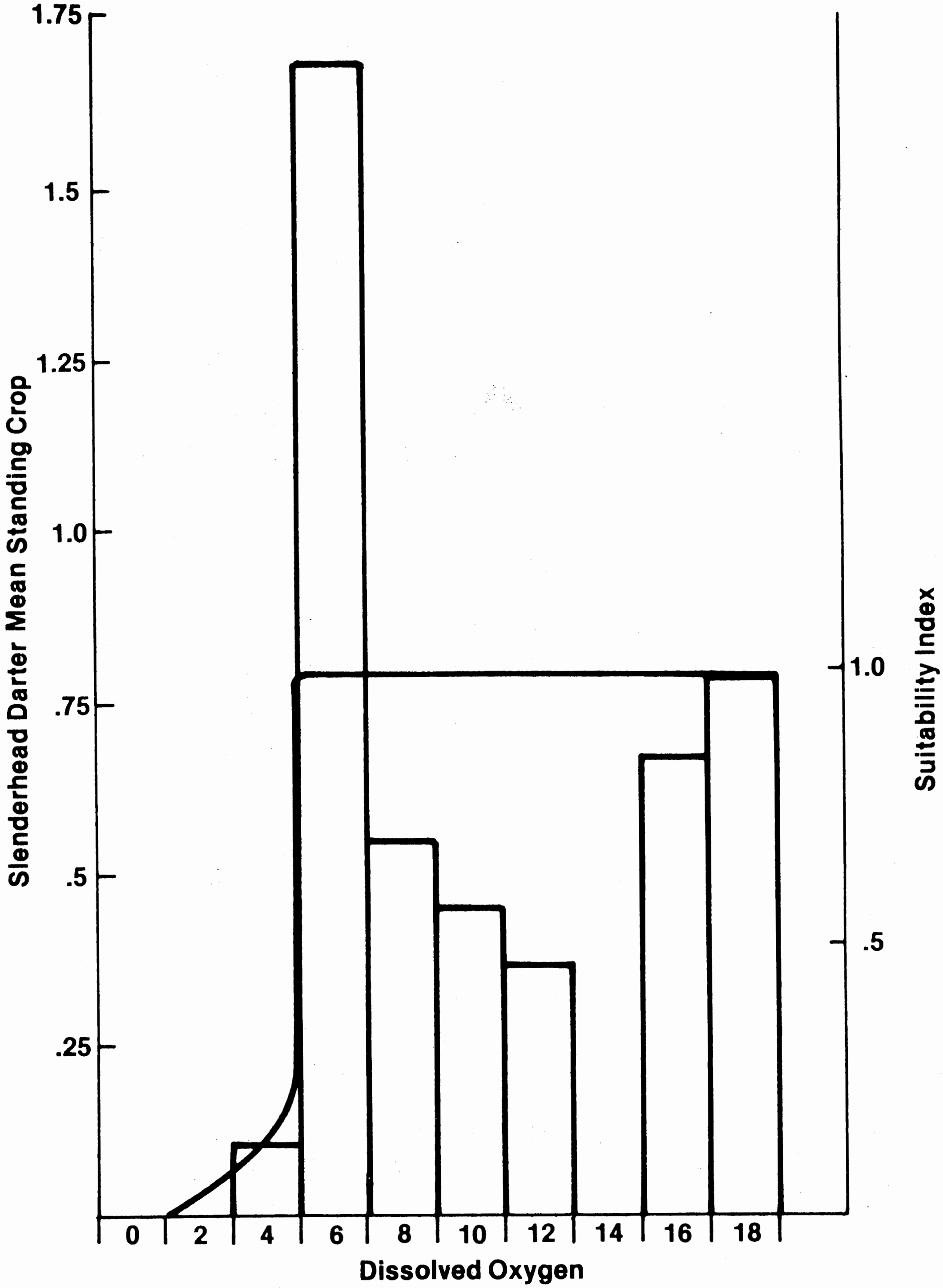


Figure 18. Relationship between slenderhead darter mean standing crop (kg/ha) and dissolved oxygen (mg/l).

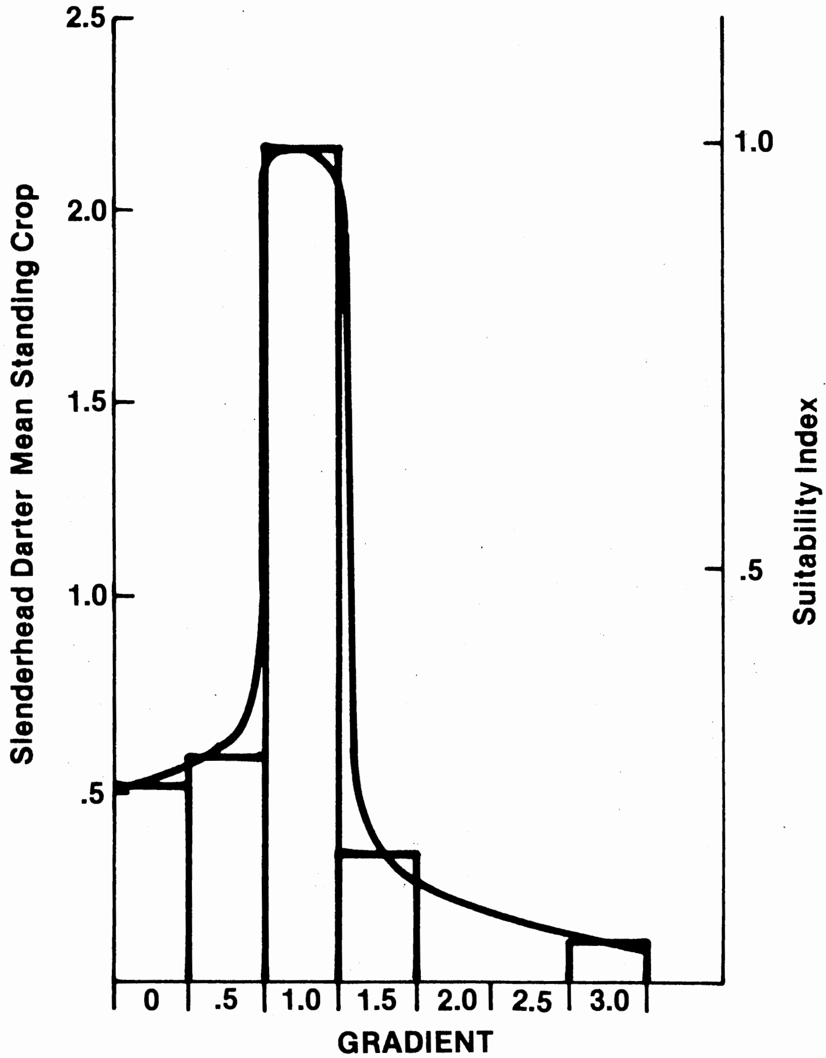


Figure 19. Relationship between slenderhead darter mean standing crop (kg/ha) and gradient (m/km).

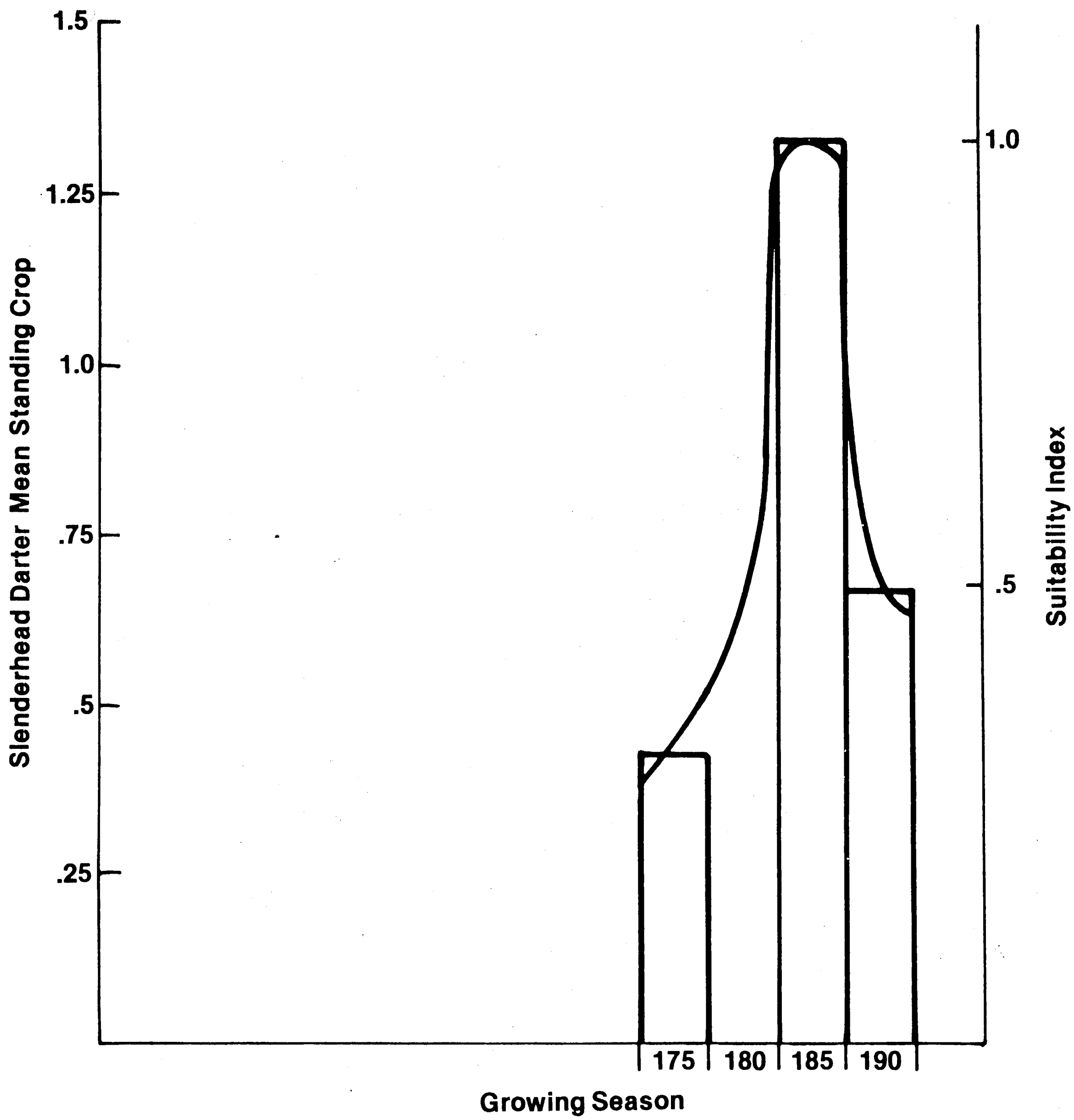


Figure 20. Relationship between slenderhead darter mean standing crop (kg/ha) and growing season (frost-free days).

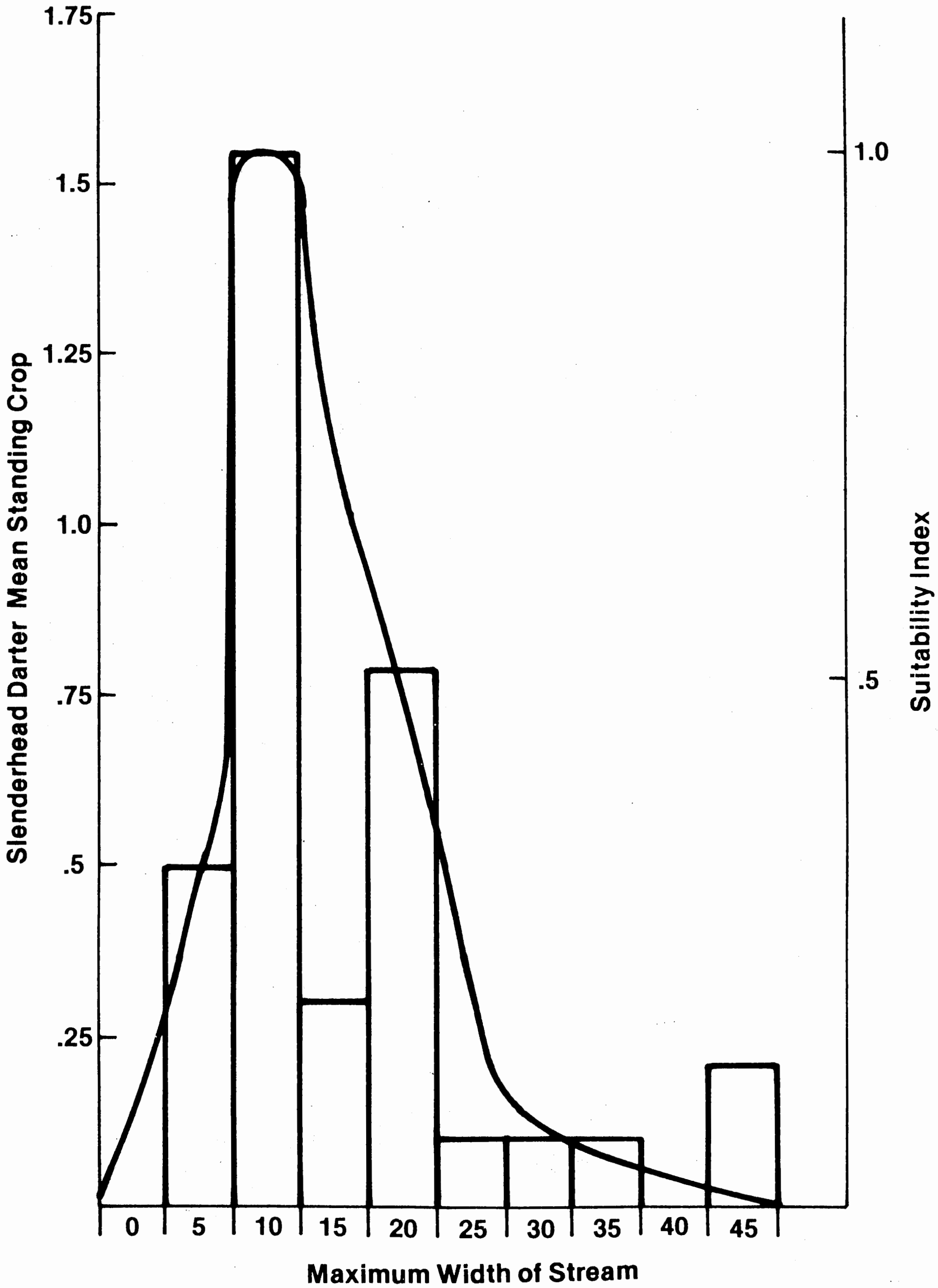


Figure 21. Relationship between slenderhead darter mean standing crop (kg/ha) and maximum stream width (m).

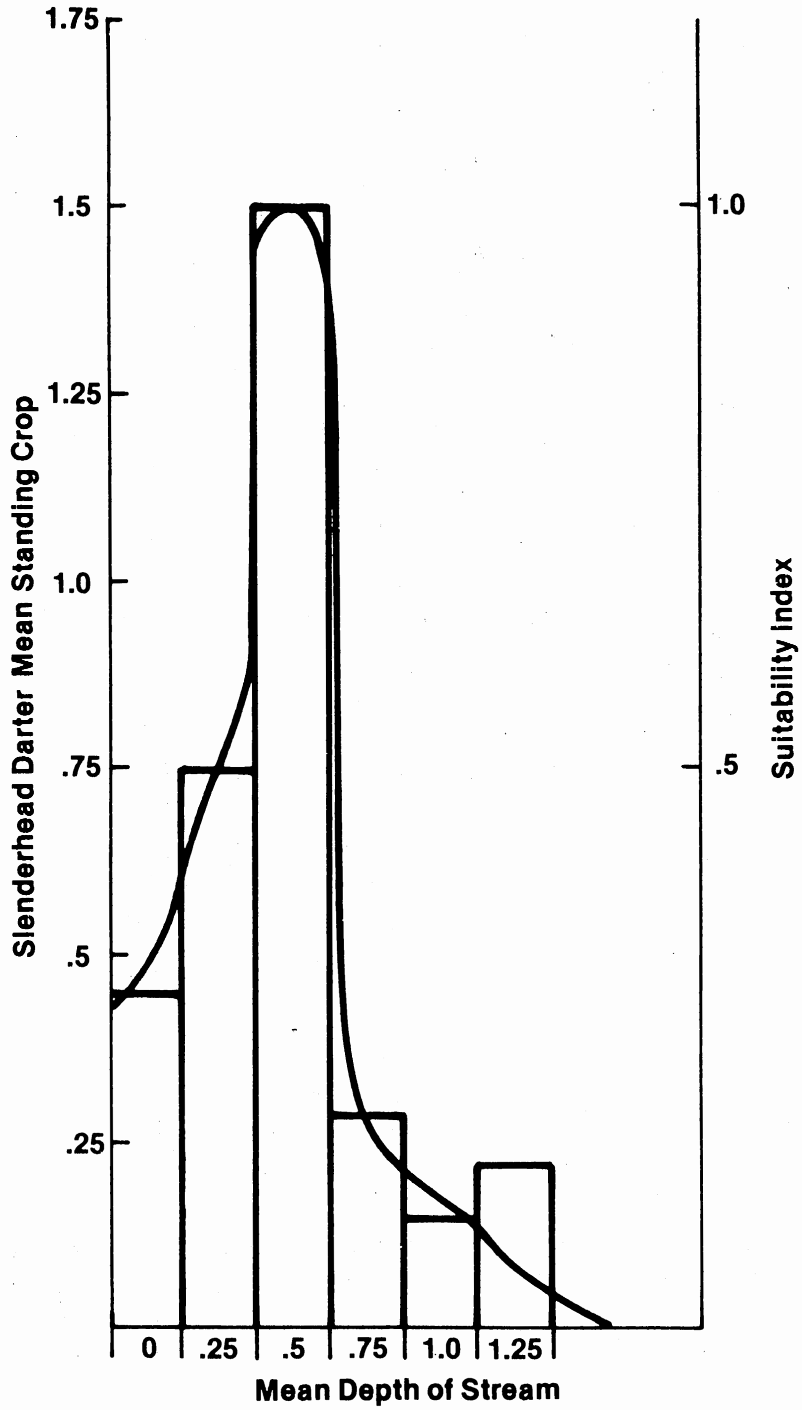


Figure 22. Relationship between slenderhead darter mean standing crop (kg/ha) and mean stream depth (m).

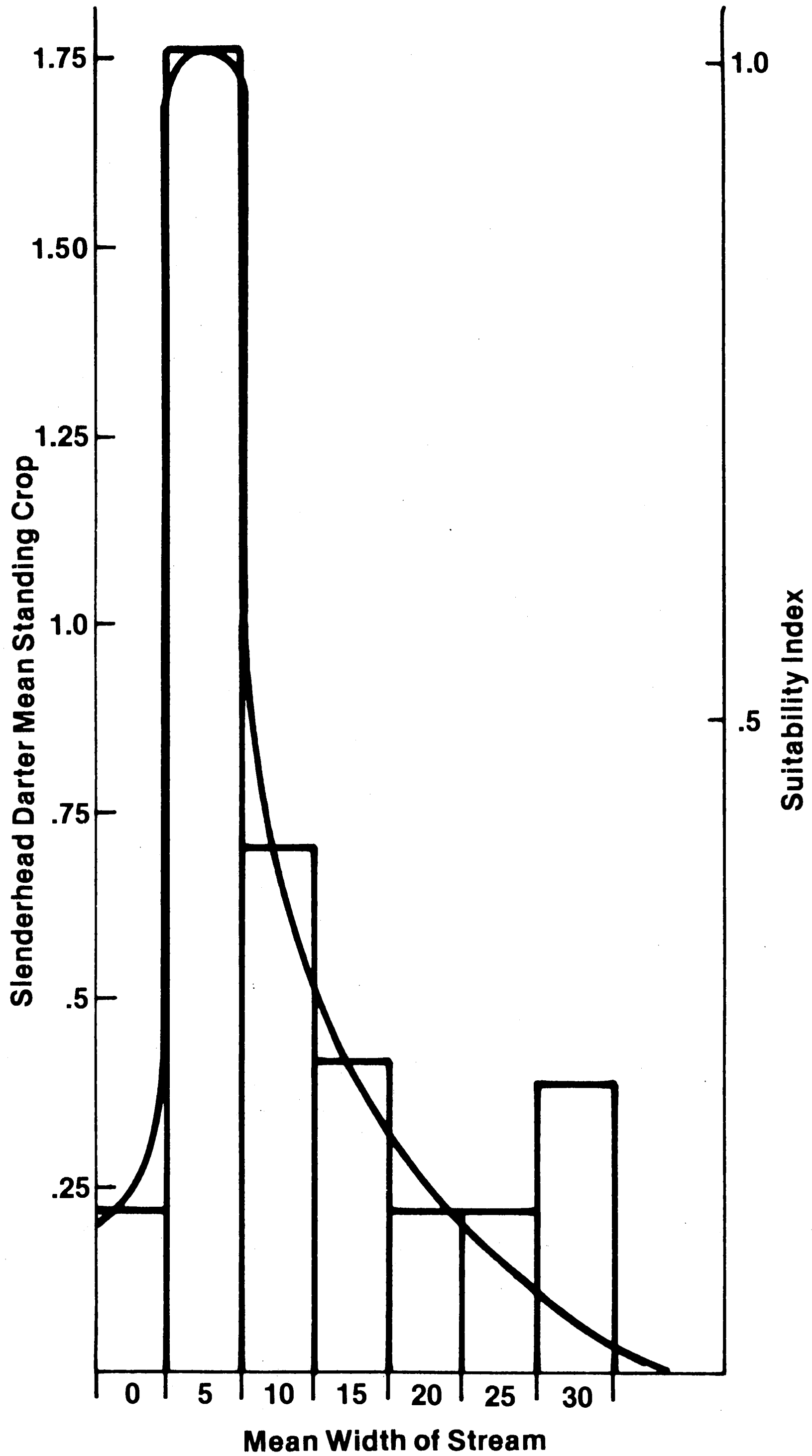


Figure 23. Relationship between slenderhead darter mean standing crop (kg/ha) and mean stream width (m).

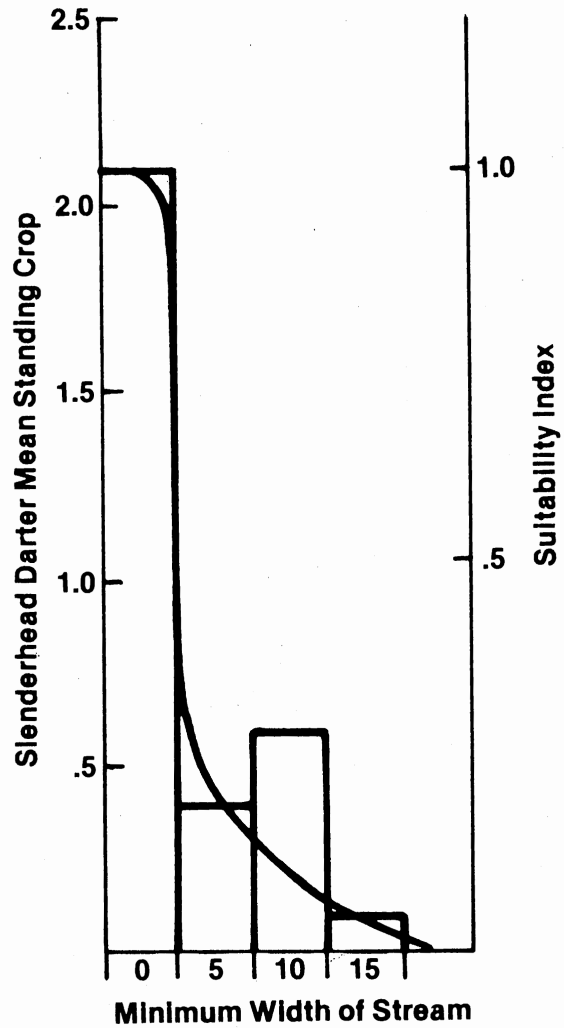


Figure 24. Relationship between slenderhead darter mean standing crop (kg/ha) and minimum stream width (m).

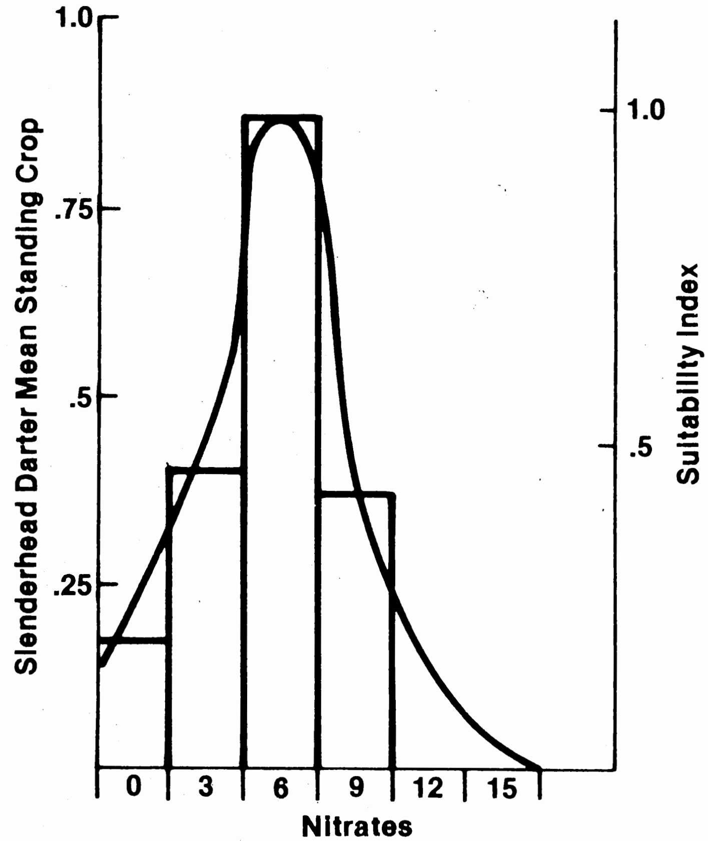


Figure 25. Relationship between slenderhead darter mean standing crop (kg/ha) and nitrates (mg/l).

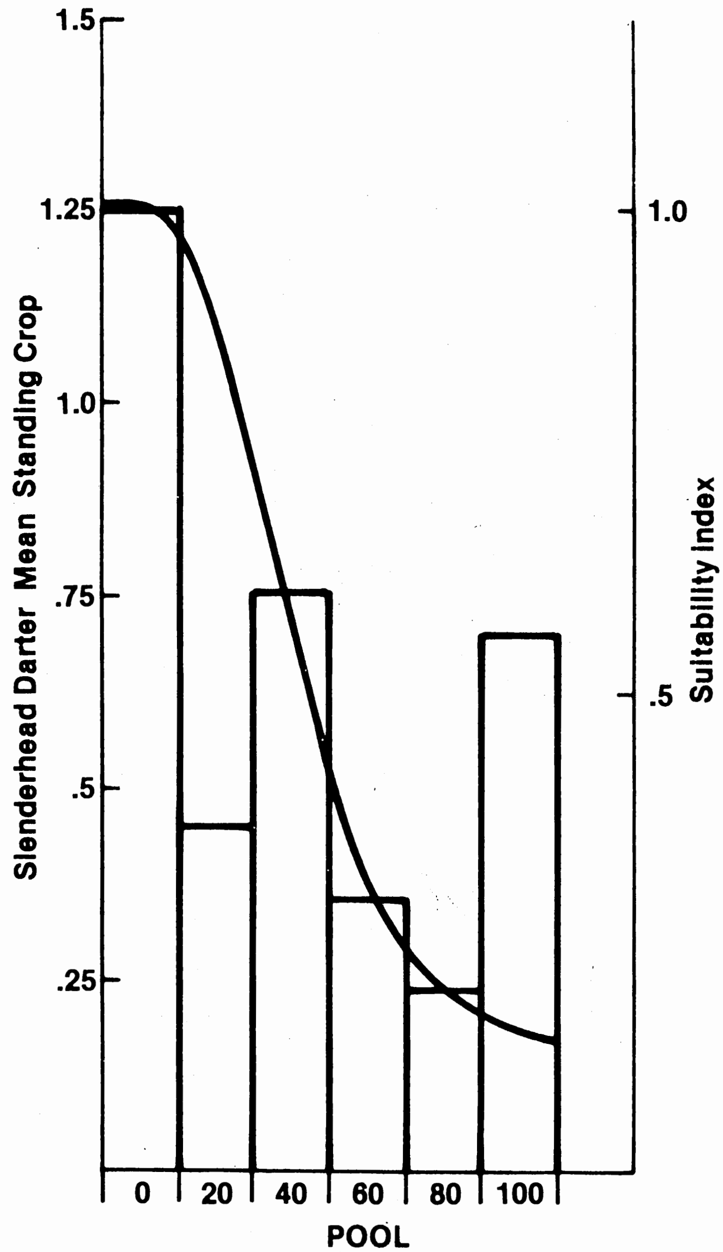


Figure 26. Relationship between slenderhead darter mean standing crop (kg/ha) and percent pool.

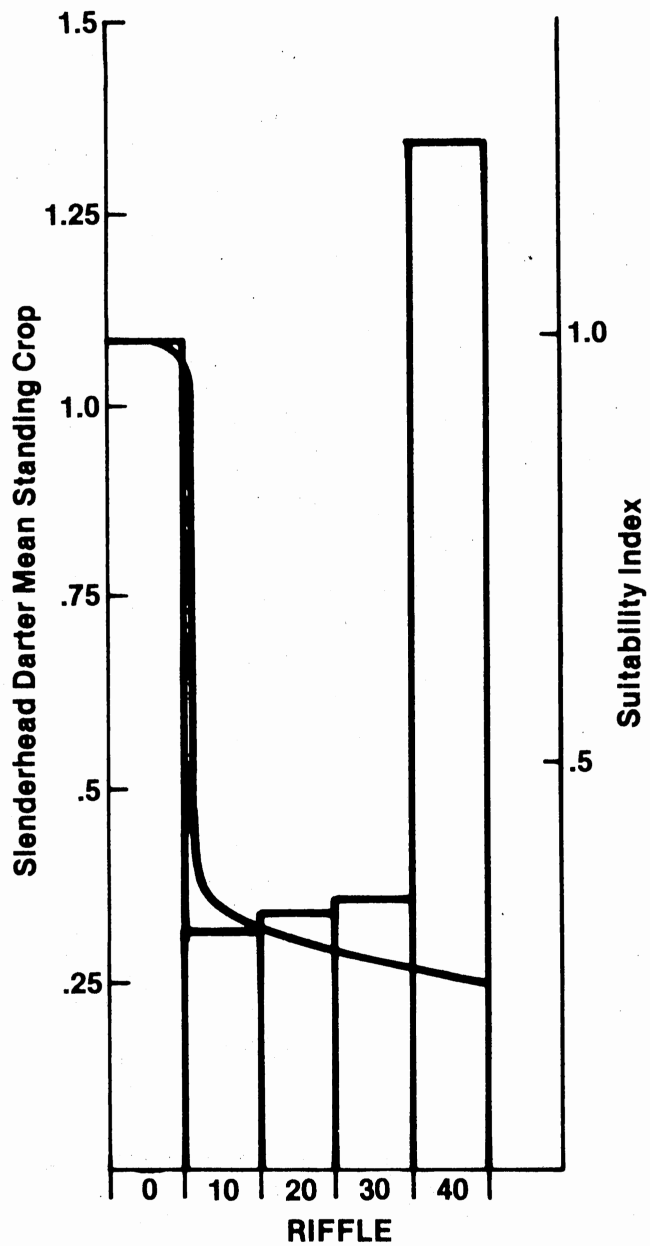


Figure 27. Relationship between slenderhead darter mean standing crop (kg/ha) and percent riffle.

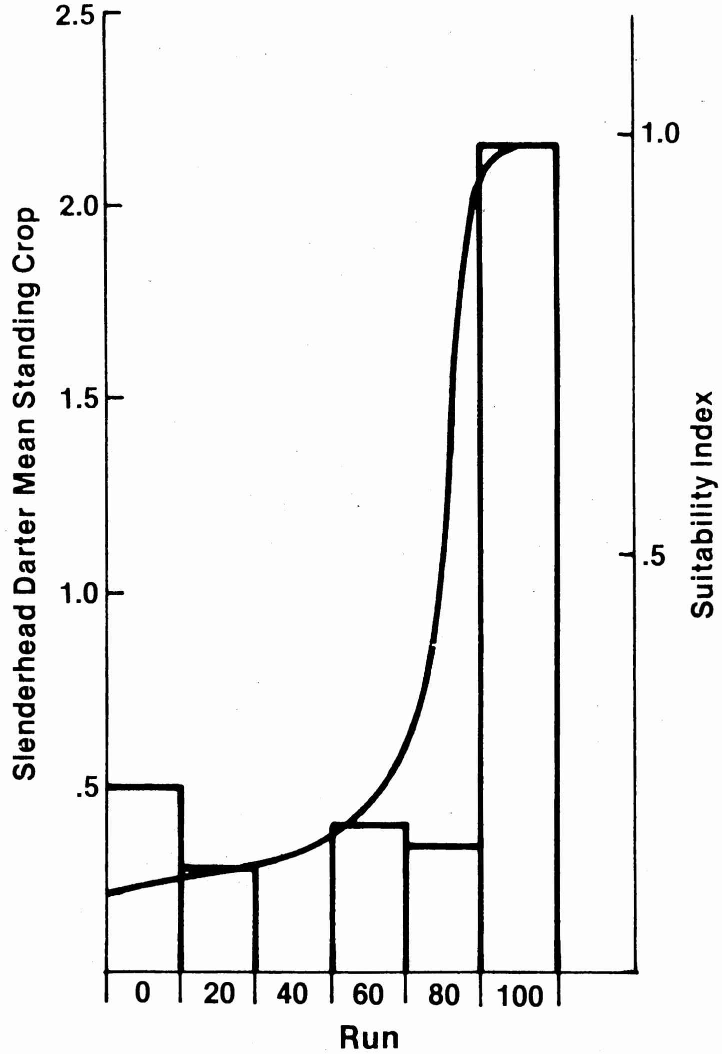


Figure 28. Relationship between slenderhead darter mean standing crop (kg/ha) and percent run.

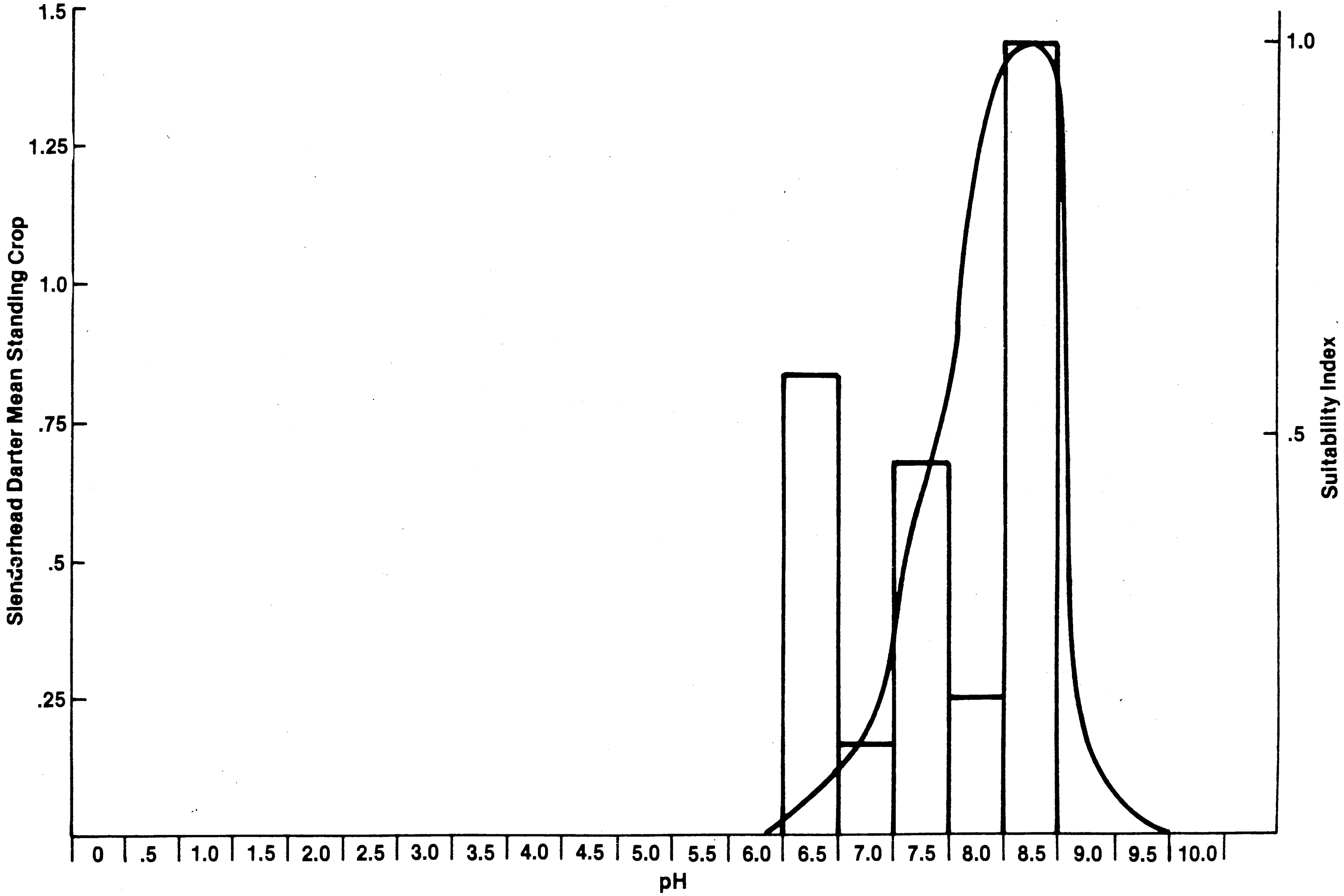


Figure 29. Relationship between slenderhead darter mean standing crop (kg/ha) and pH.

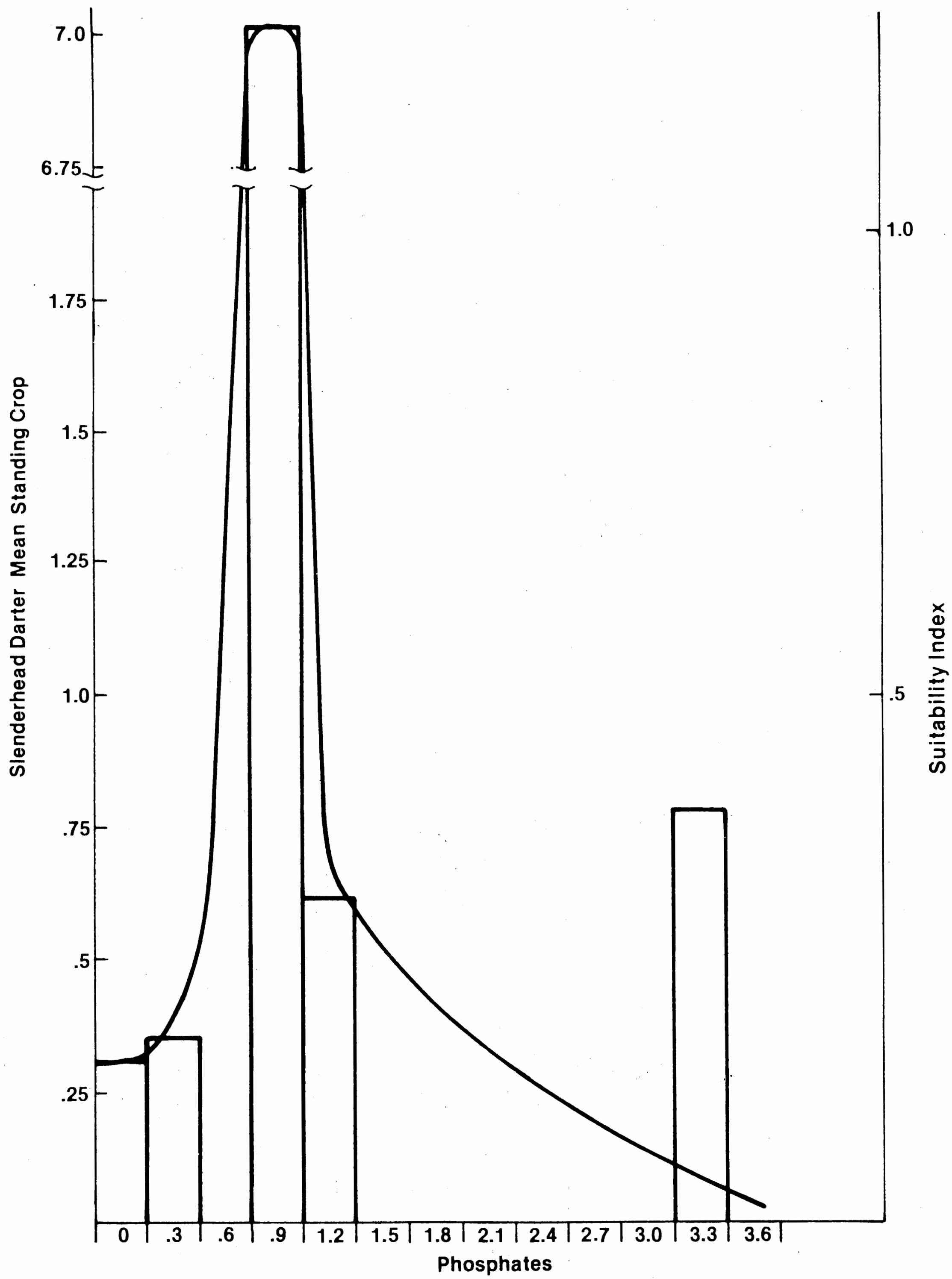


Figure 30. Relationship between slenderhead darter mean standing crop (kg/ha) and phosphates (mg/l).

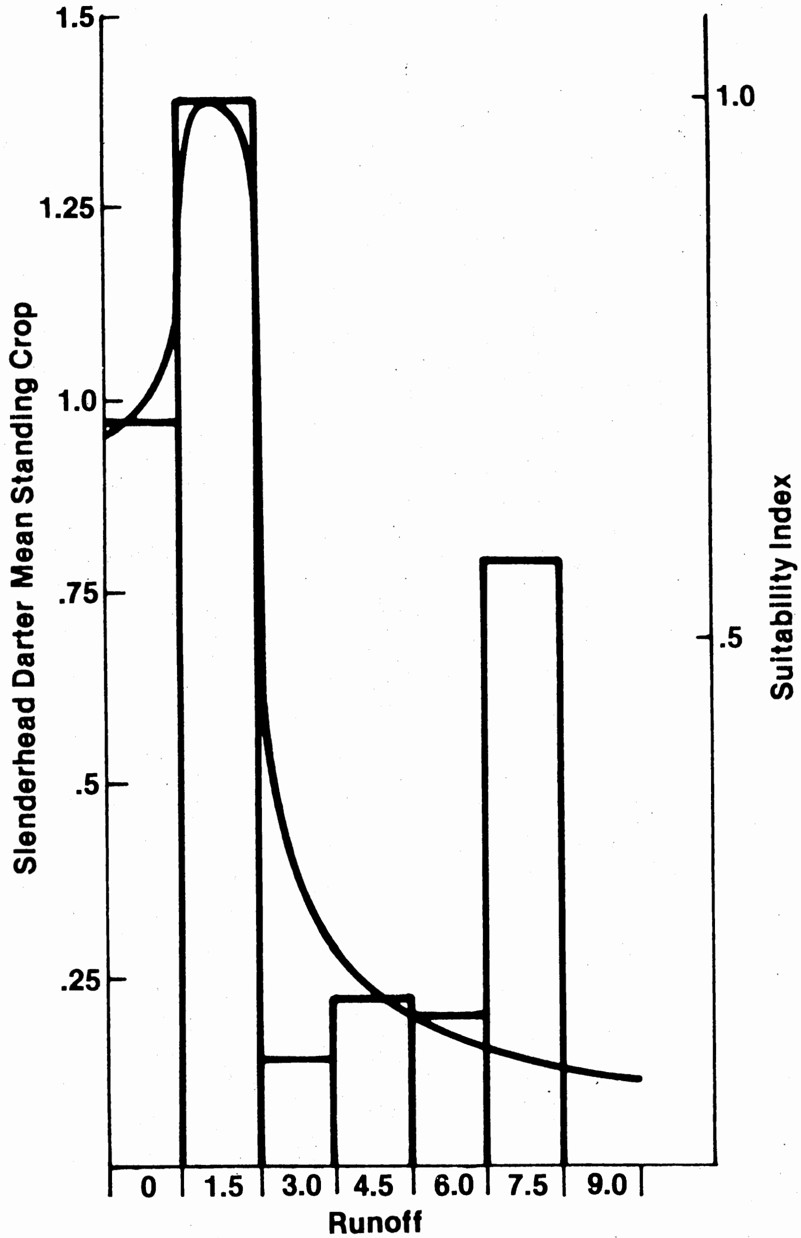


Figure 31. Relationship between slenderhead darter mean standing crop (kg/ha) and runoff (in/yr).

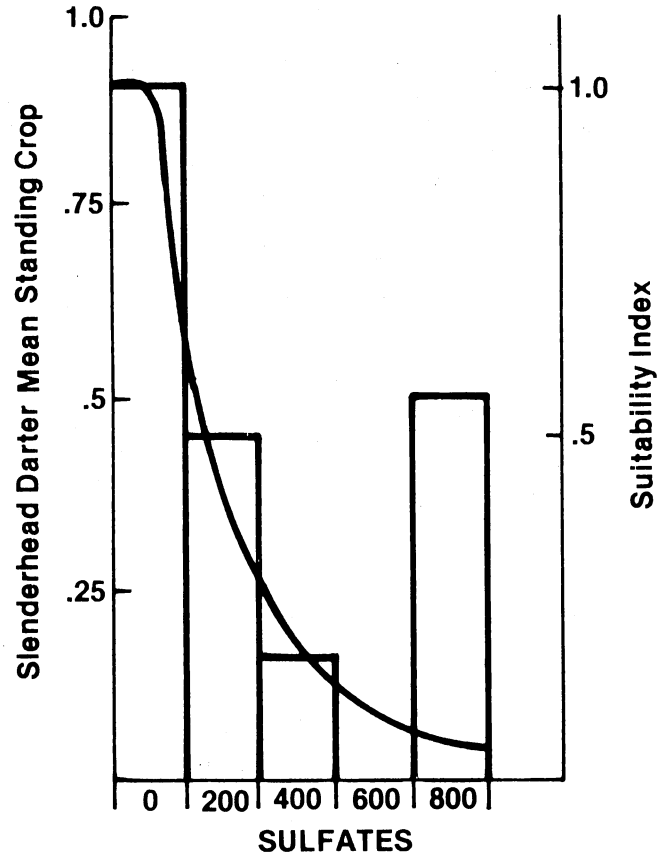


Figure 32. Relationship between slenderhead darter mean standing crop (ka/ha) and sulfates (mg/l).

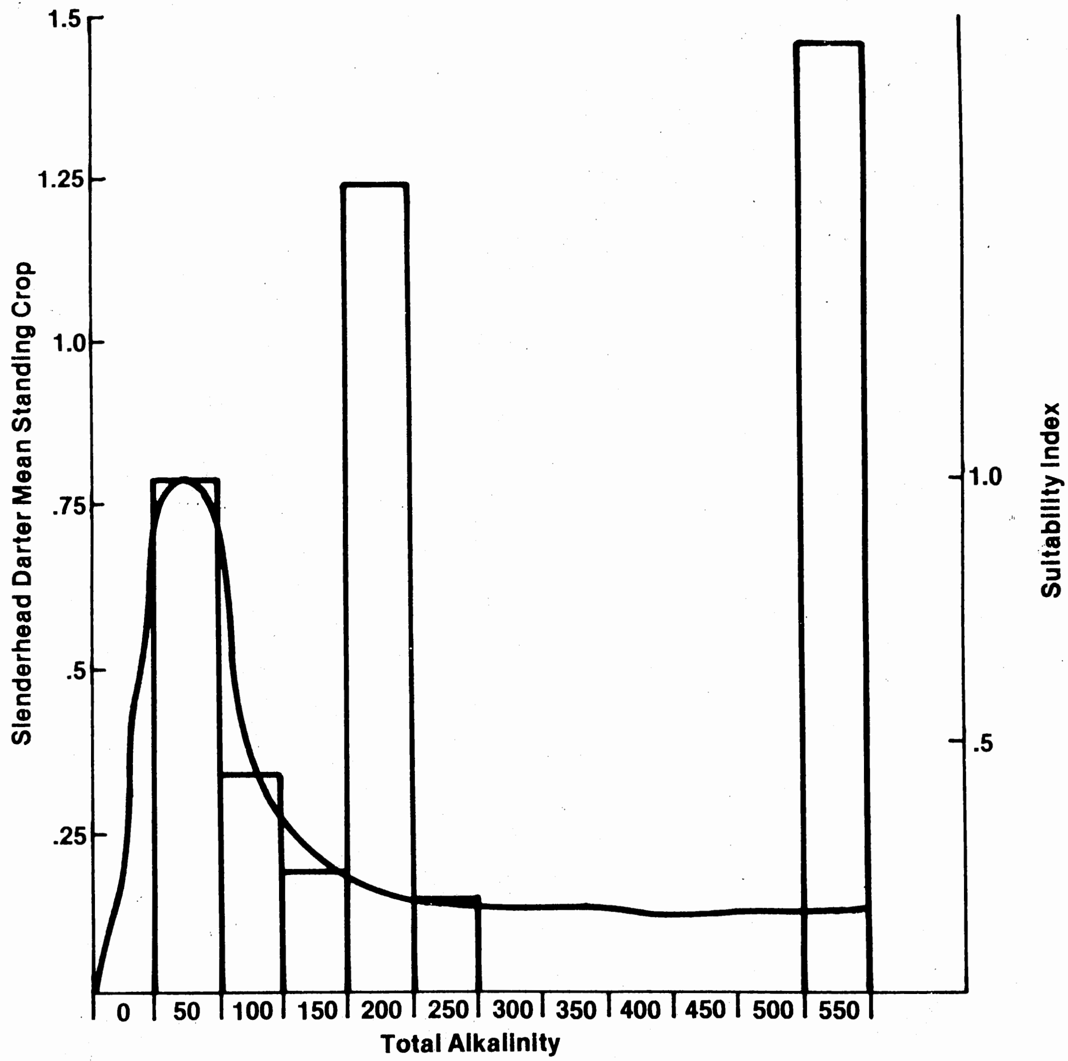


Figure 33. Relationship between slenderhead darter mean standing crop (kg/ha) and total alkalinity (mg/l).

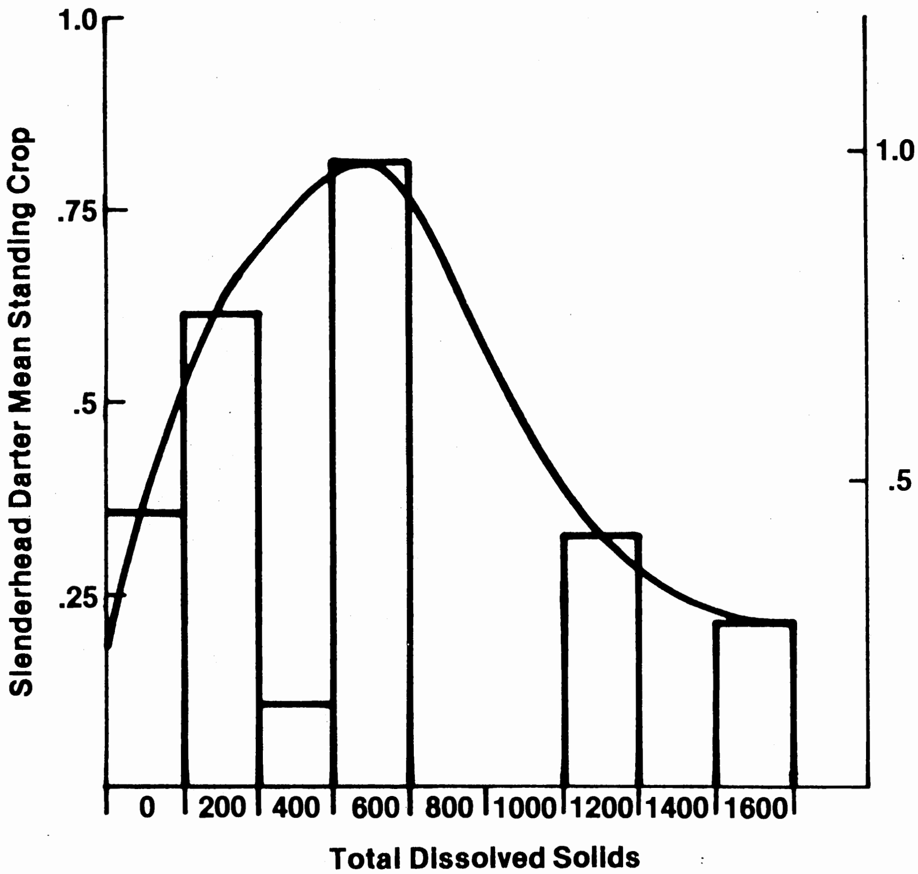


Figure 34. Relationship between slenderhead darter mean standing crop (kg/ha) and total dissolved solids (mg/l).

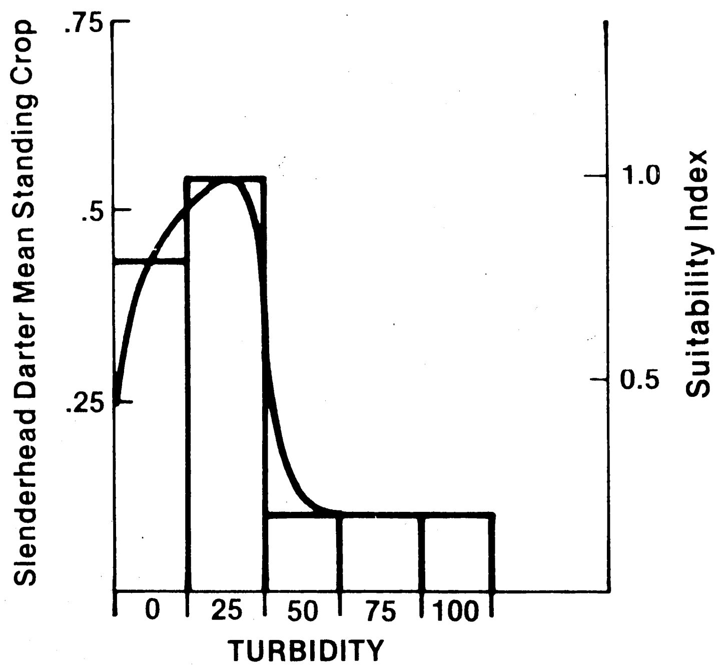


Figure 35. Relationship between slender-head darter mean standing crop (kg/ha) and turbidity (JTU's).

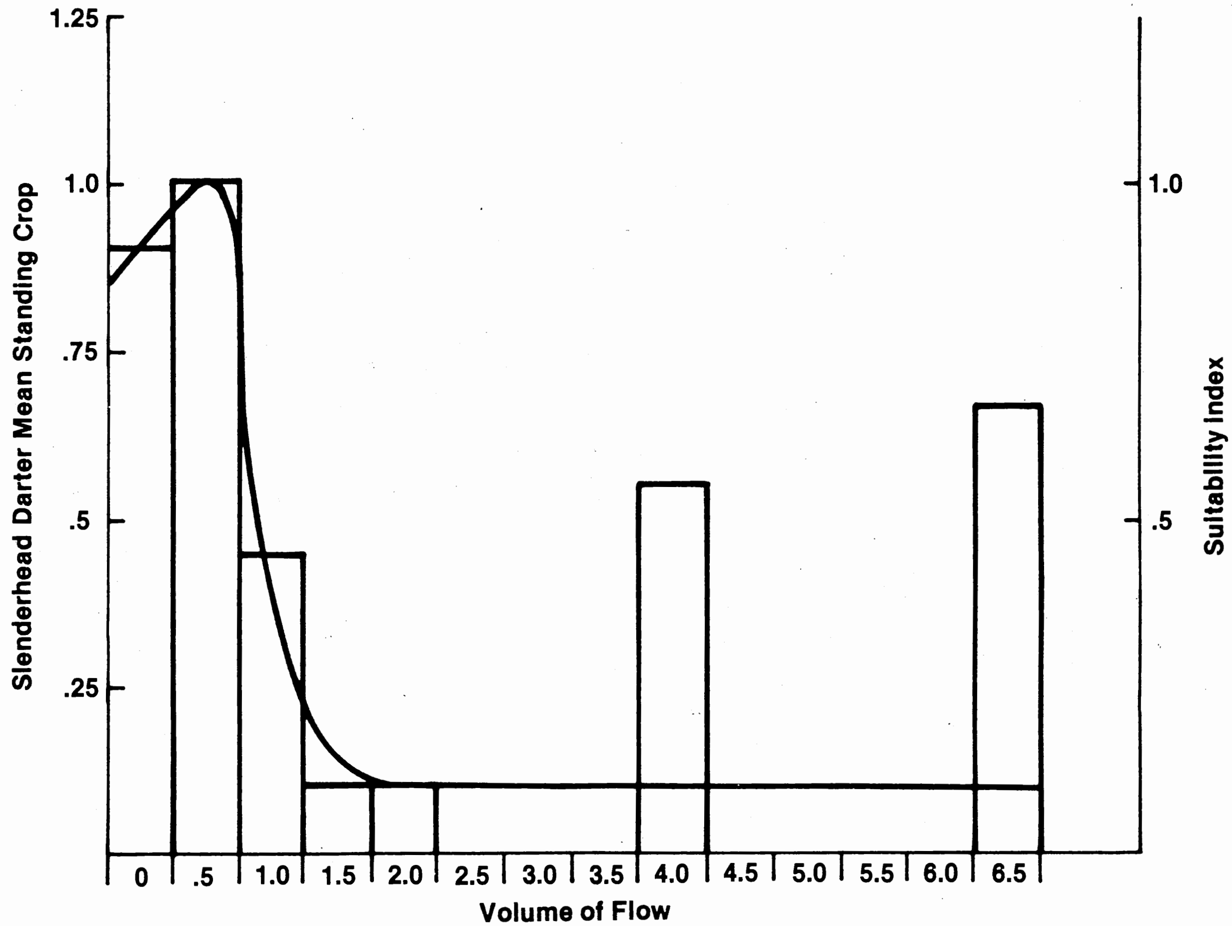


Figure 36. Relationship between slenderhead darter mean standing crop (kg/ha) and volume of flow ($m^3/s$).

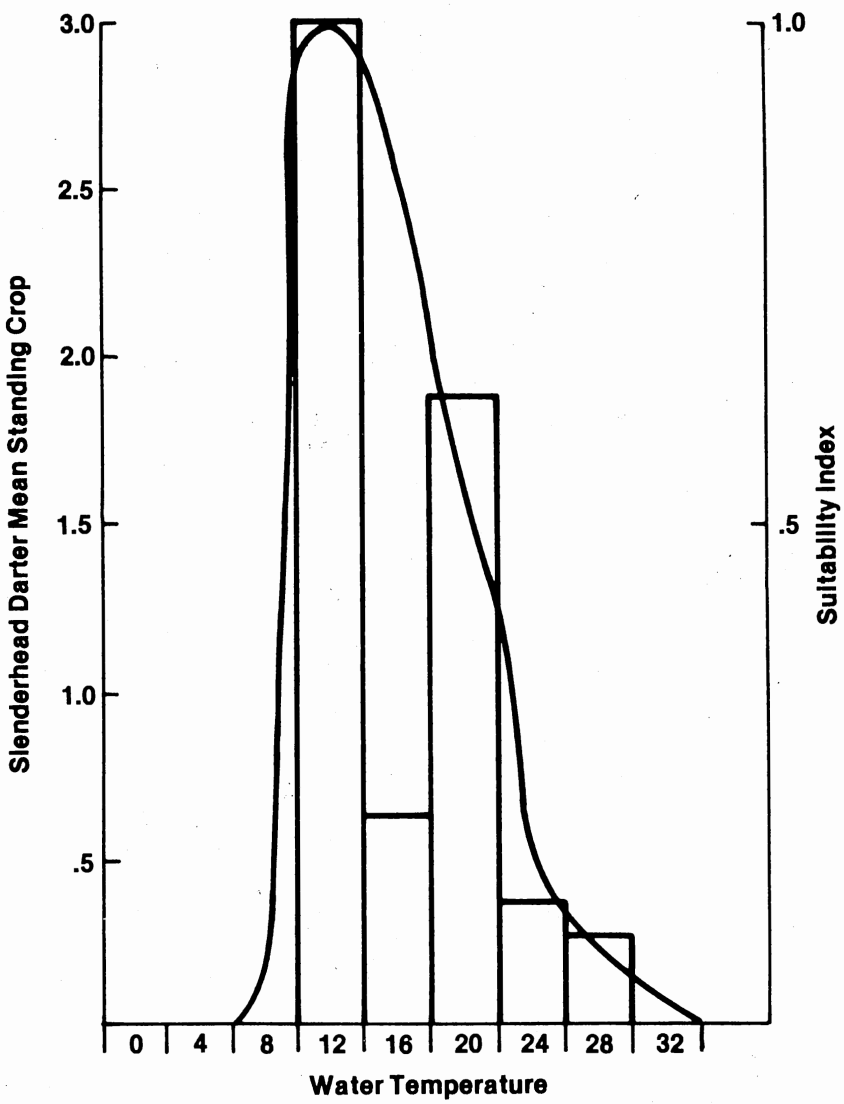


Figure 37. Relationship between slenderhead darter mean standing crop (kg/ha) and water temperature (C).

APPENDIX C

ORANGETHROAT DARTER SUITABILITY CURVES

(INTERVAL RANGES, MEANS, AND N VALUES

GIVEN IN APPENDIX I)

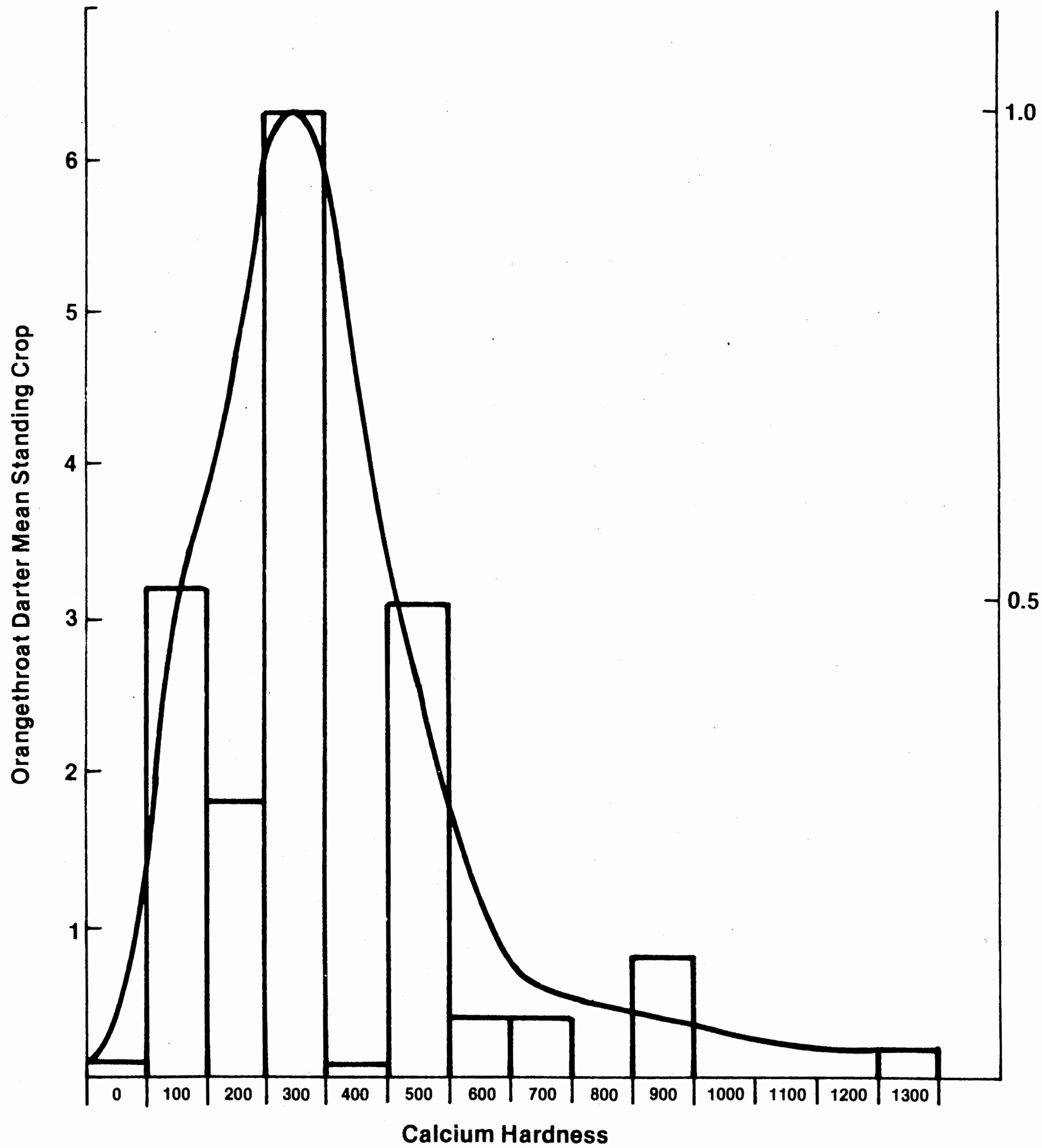


Figure 38. Relationship between orangethroat darter mean standing crop (kg/ha) and calcium hardness (mg/l).

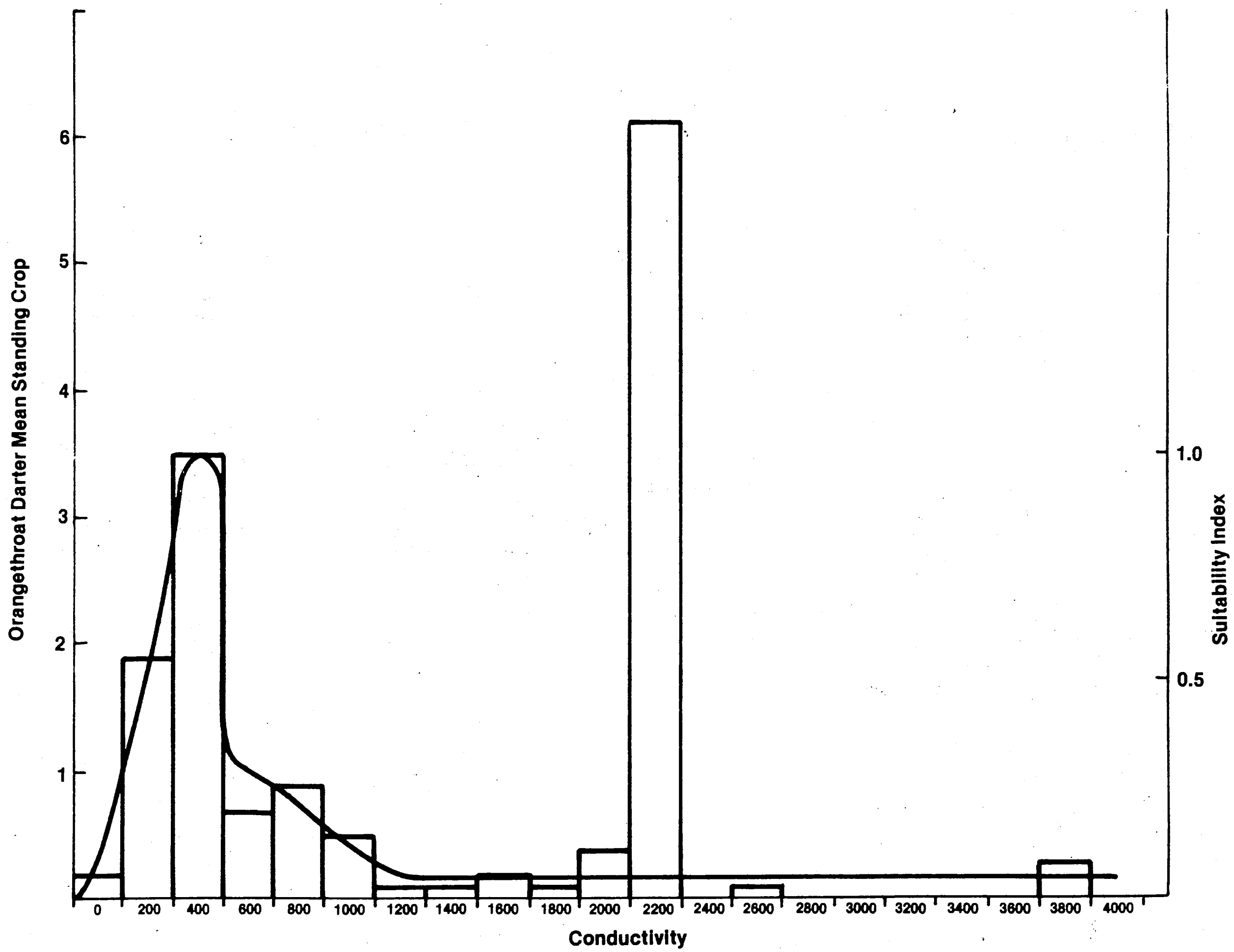


Figure 39. Relationship between orangethroat darter mean standing crop (kg/ha) and conductivity (μmhos/cm).

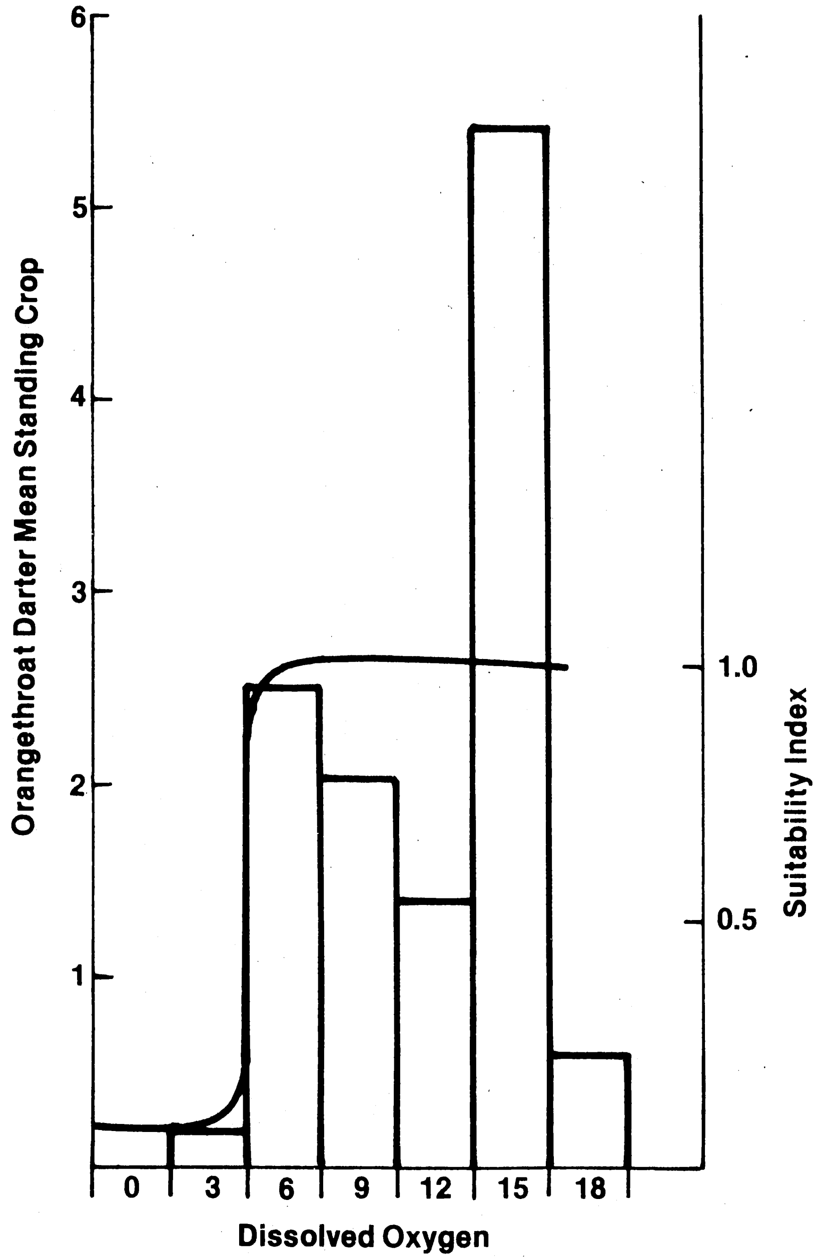


Figure 40. Relationship between orangethroat darter mean standing crop (kg/ha) and dissolved oxygen (mg/l).

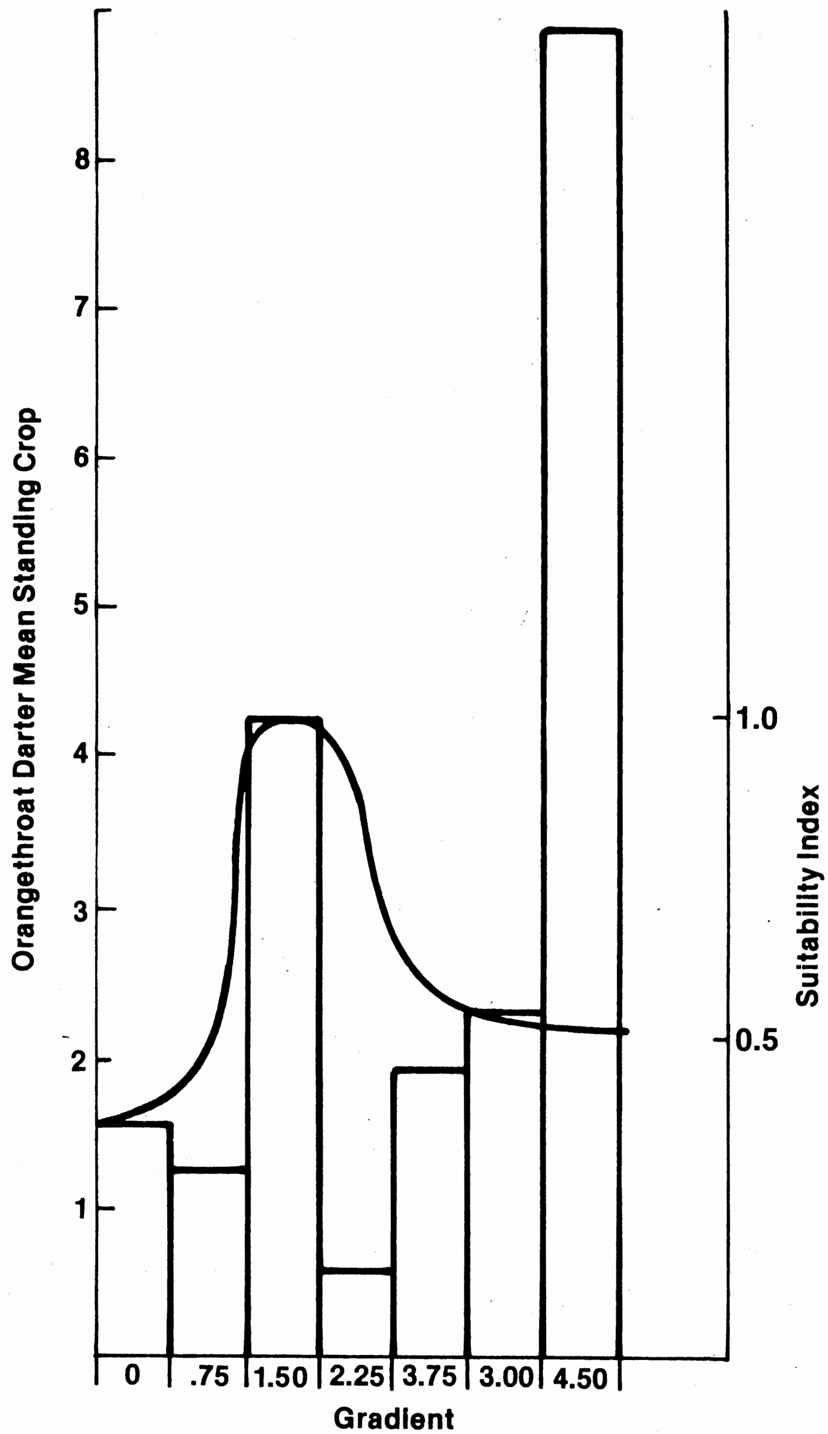


Figure 41. Relationship between orangethroat darter mean standing crop (kg/ha) and gradient (m/km).

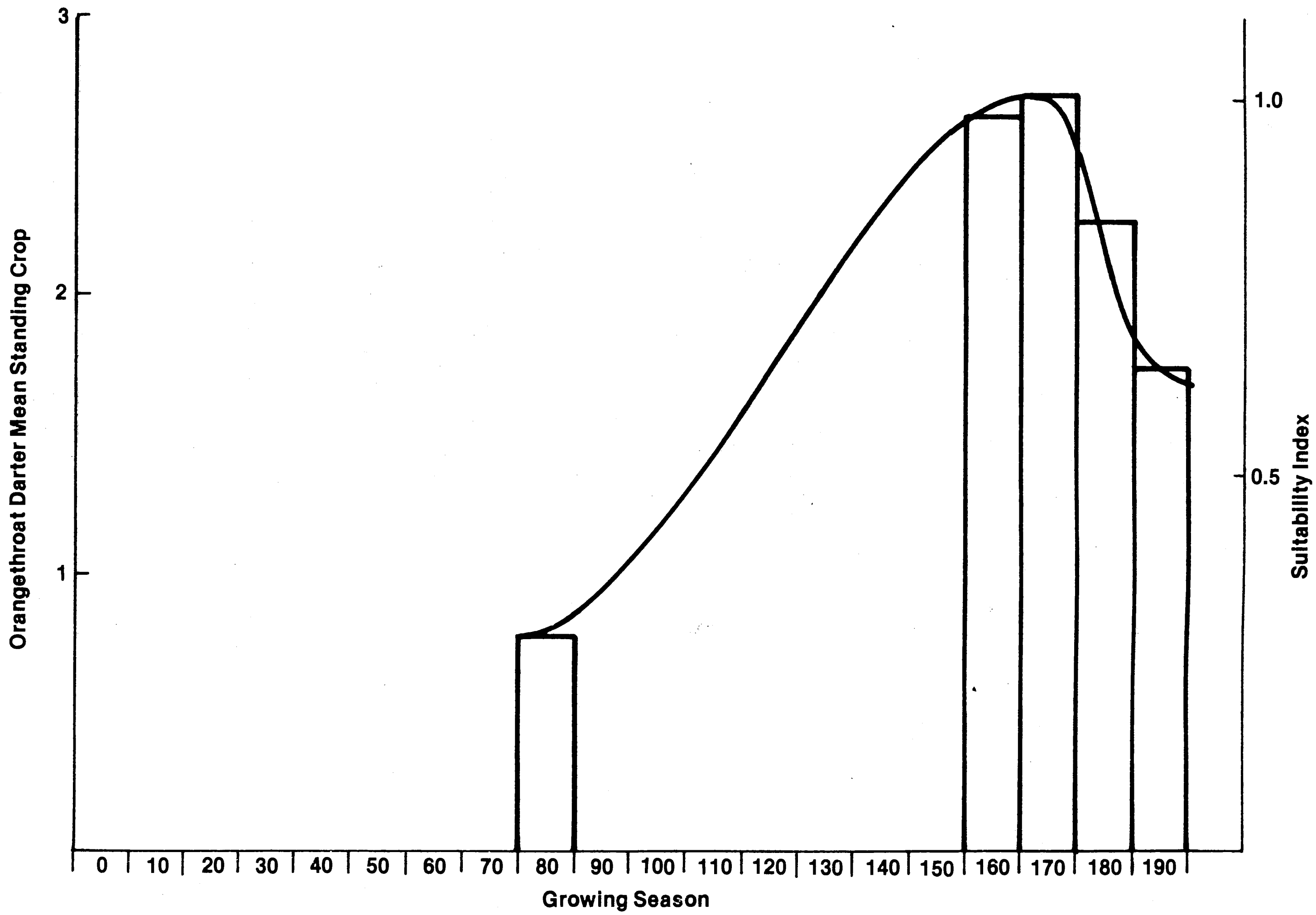


Figure 42. Relationship between orangethroat darter mean standing crop (kg/ha) and growing season (frost-free days).

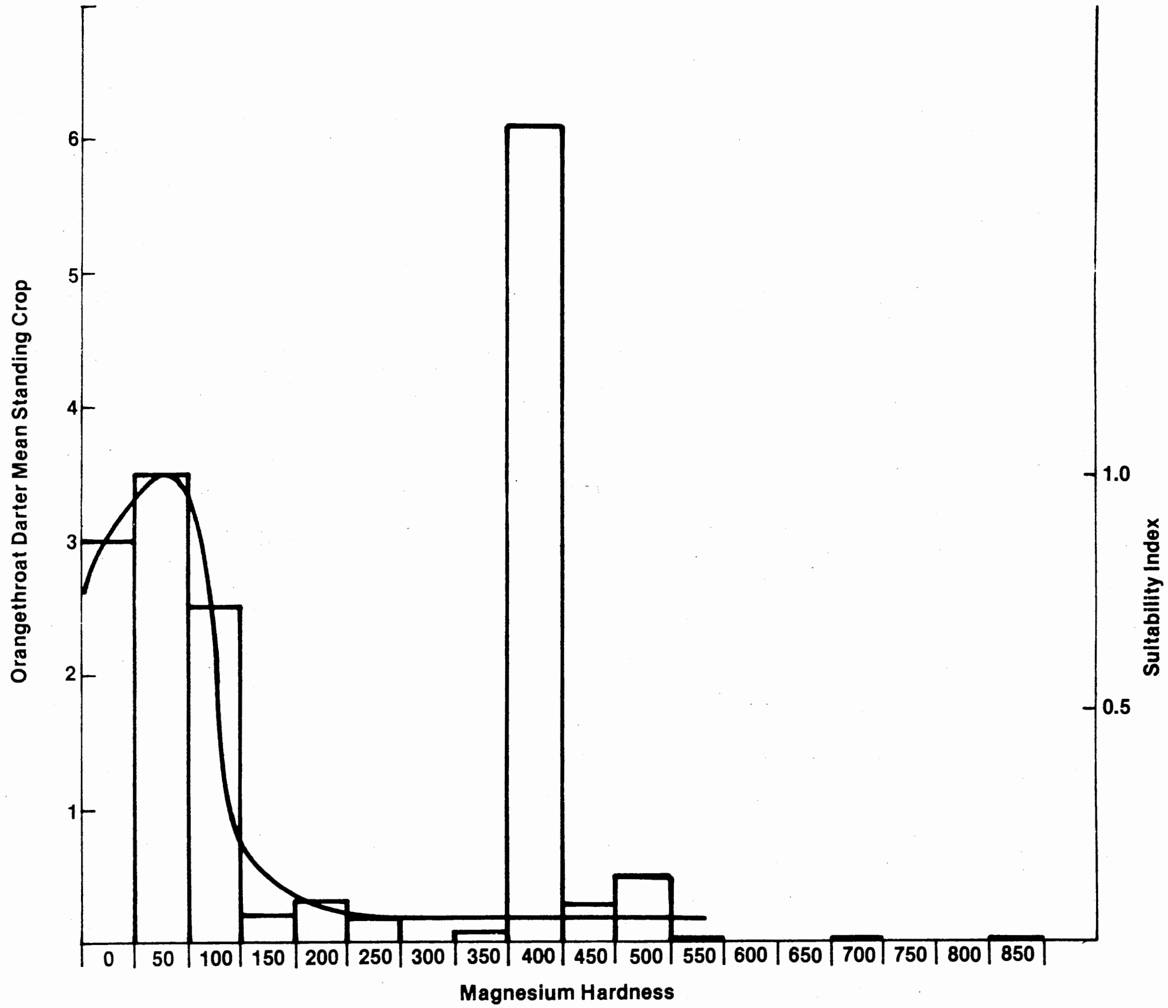


Figure 43. Relationship between orangethroat darter mean standing crop (kg/ha) and magnesium hardness (mg/l).

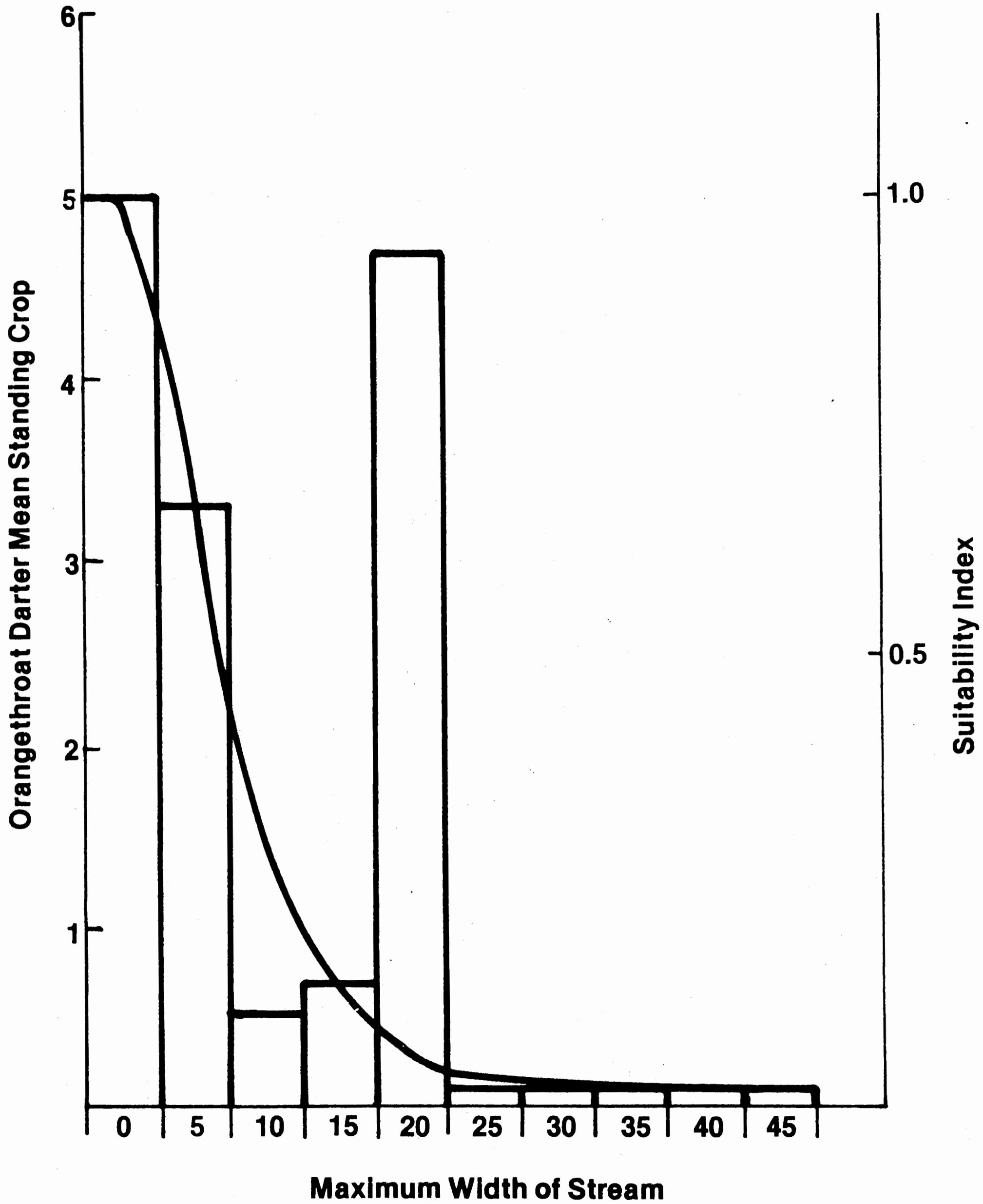


Figure 44. Relationship between orangethroat darter mean standing crop (kg/ha) and maximum stream width (m).

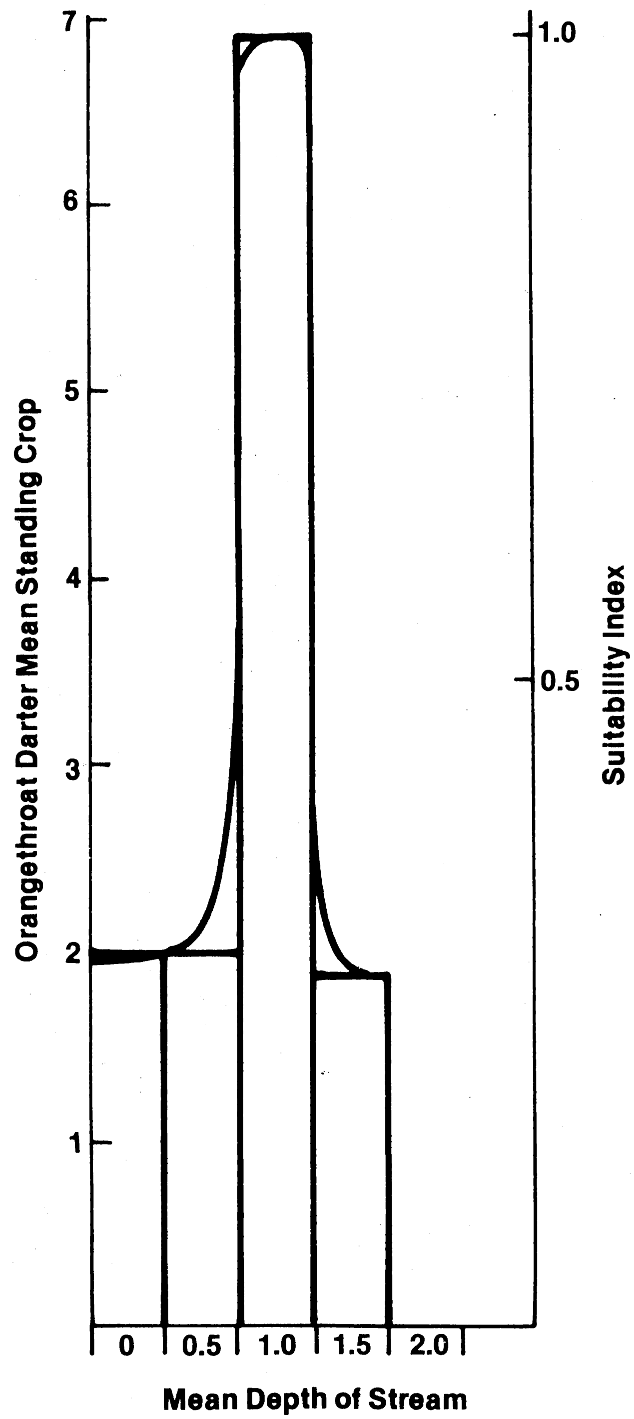


Figure 45. Relationship between orangethroat darter mean standing crop (kg/ha) and mean stream depth (m).

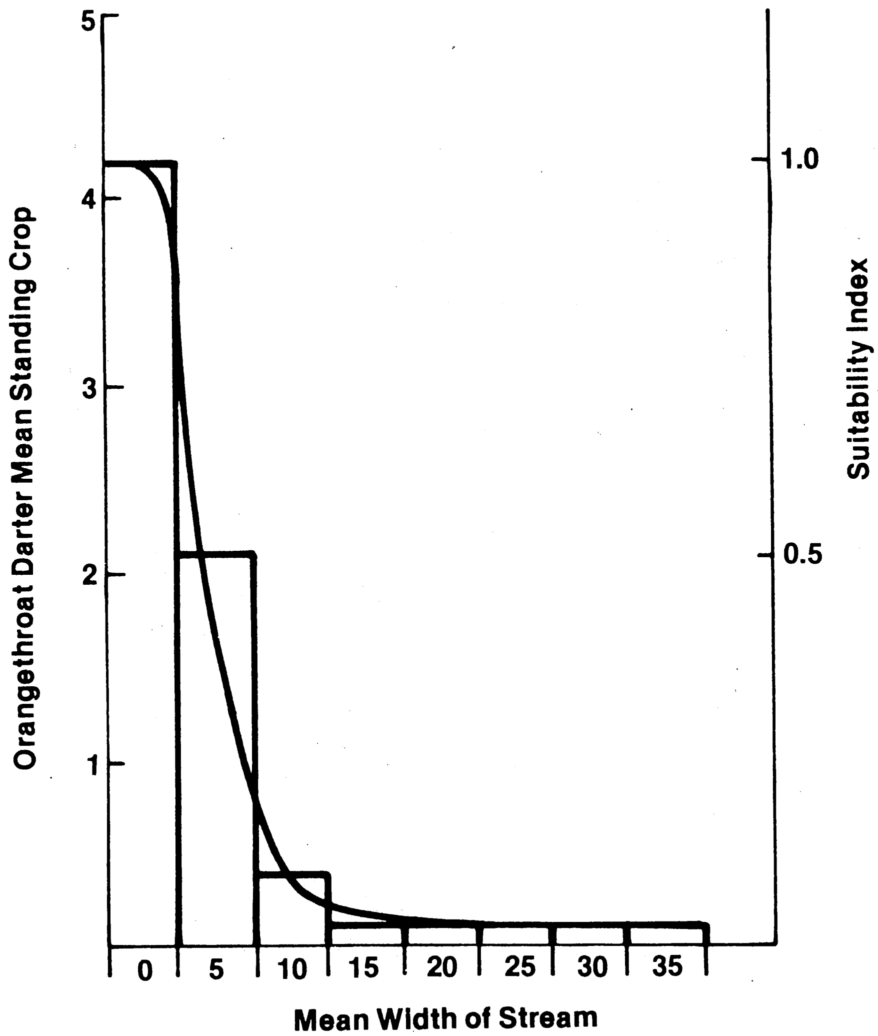


Figure 46. Relationship between orangethroat darter mean standing crop (kg/ha) and mean stream width (m).

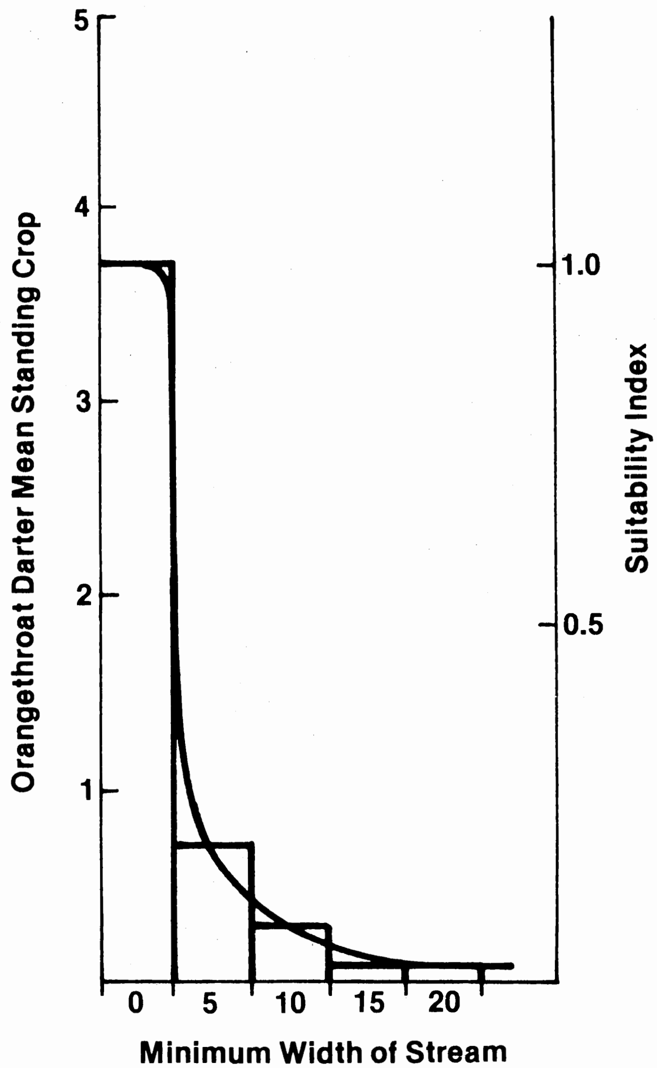


Figure 47. Relationship between orange-throat darter mean standing crop (kg/ha) and minimum stream width (m).

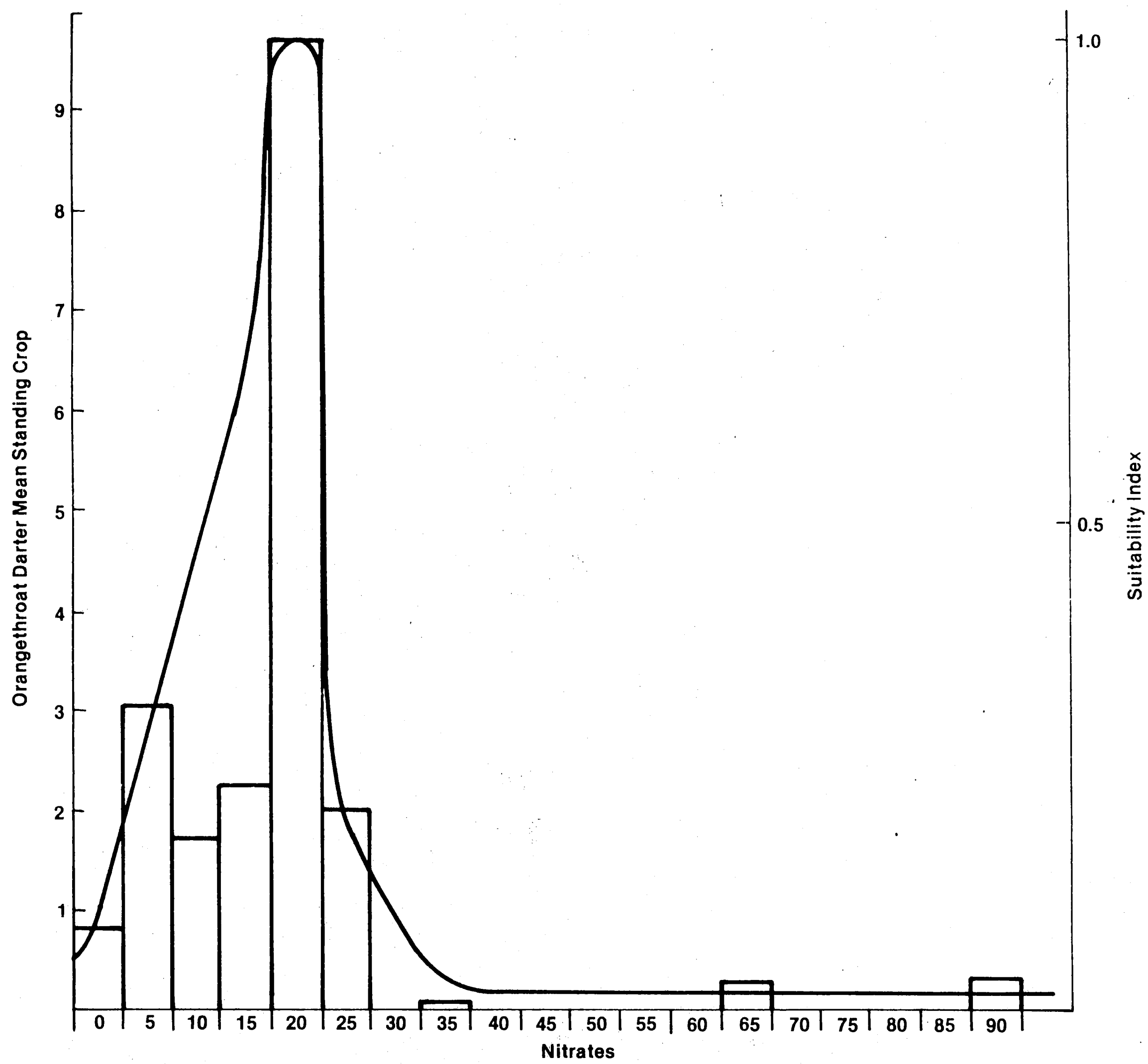


Figure 48. Relationship between orangethroat darter mean standing crop (kg/ha) and nitrates (mg/l).

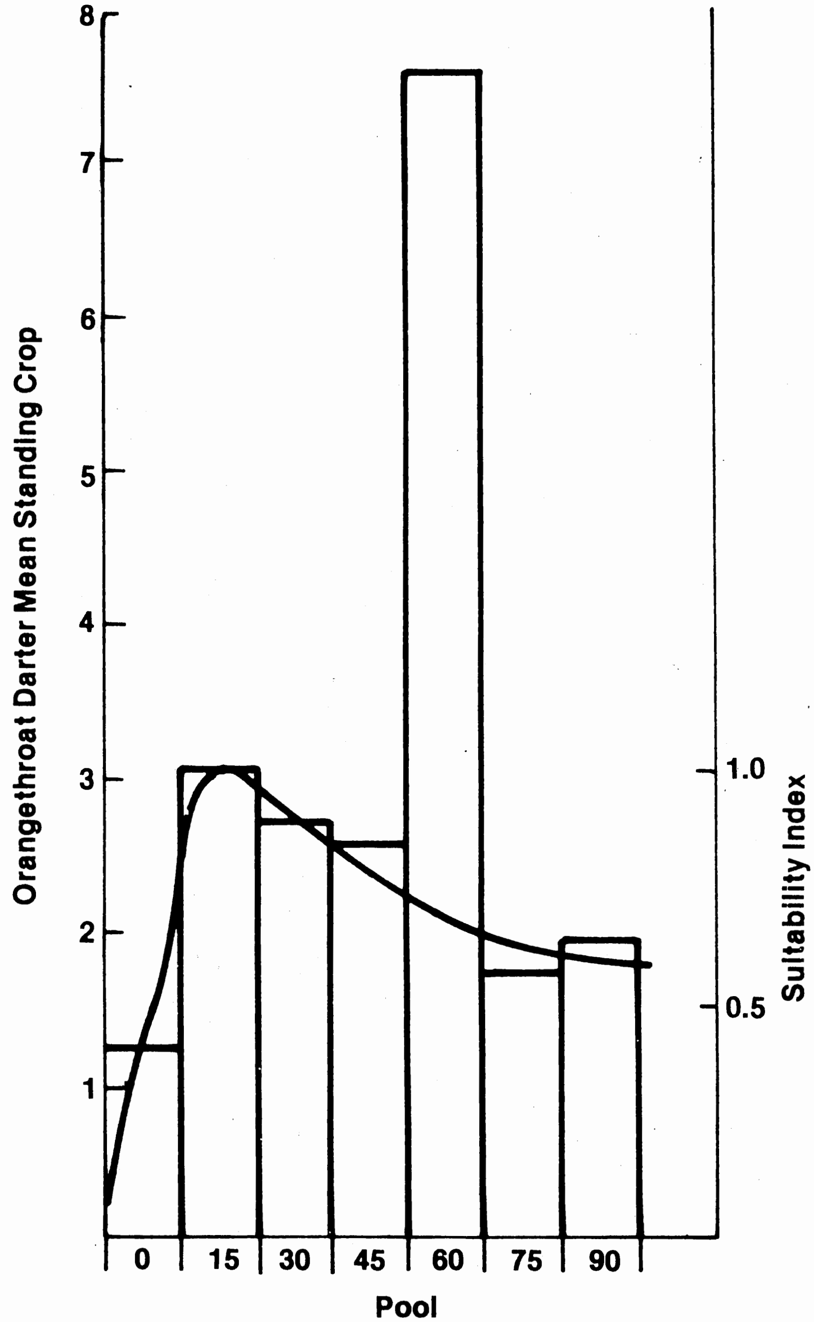


Figure 49. Relationship between orangethroat darter mean standing crop (kg/ha) and percent pool.

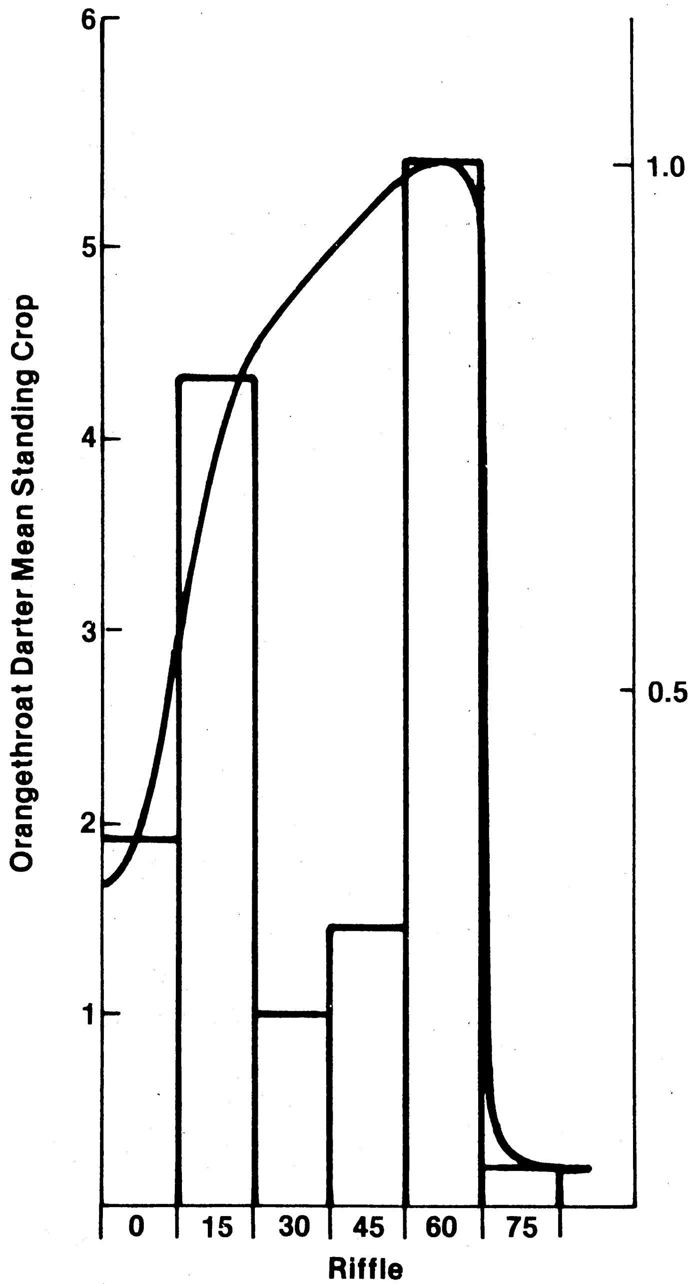


Figure 50. Relationship between orangethroat darter mean standing crop (kg/ha) and percent riffle.

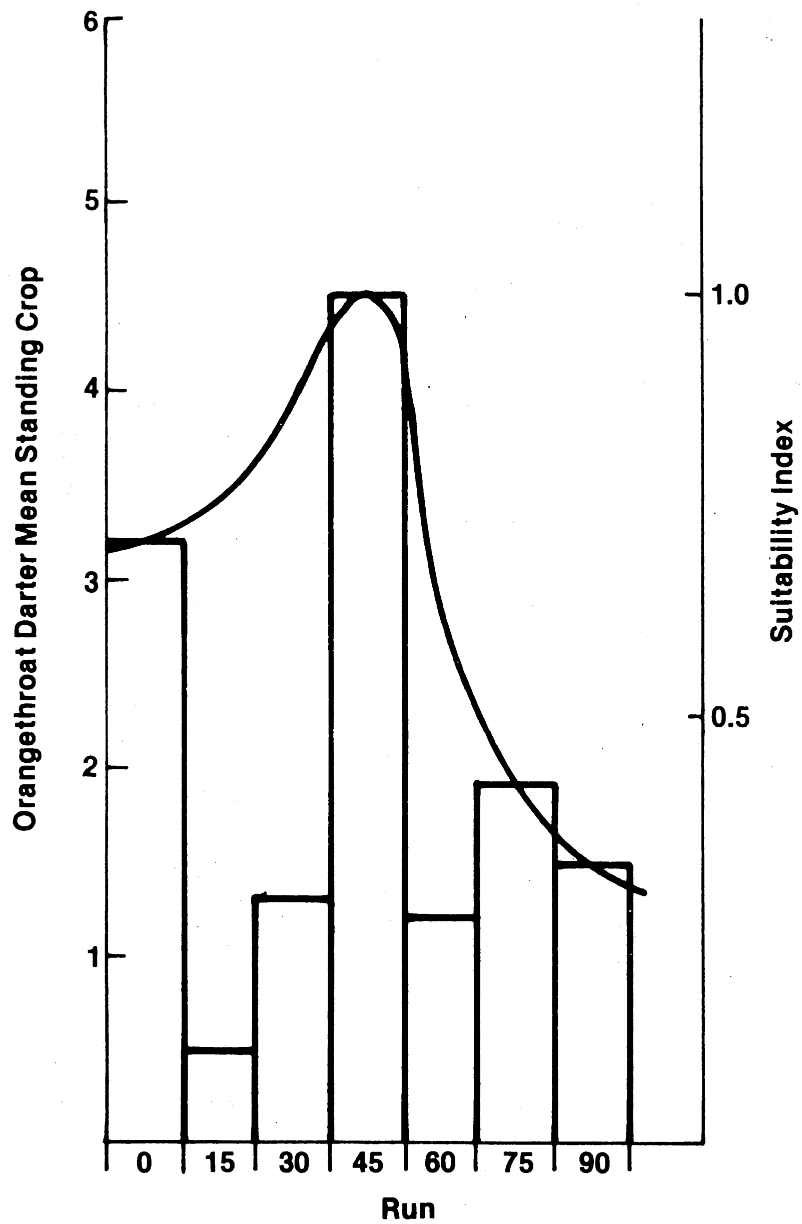


Figure 51. Relationship between orangethroat darter mean standing crop (kg/ha) and percent run.

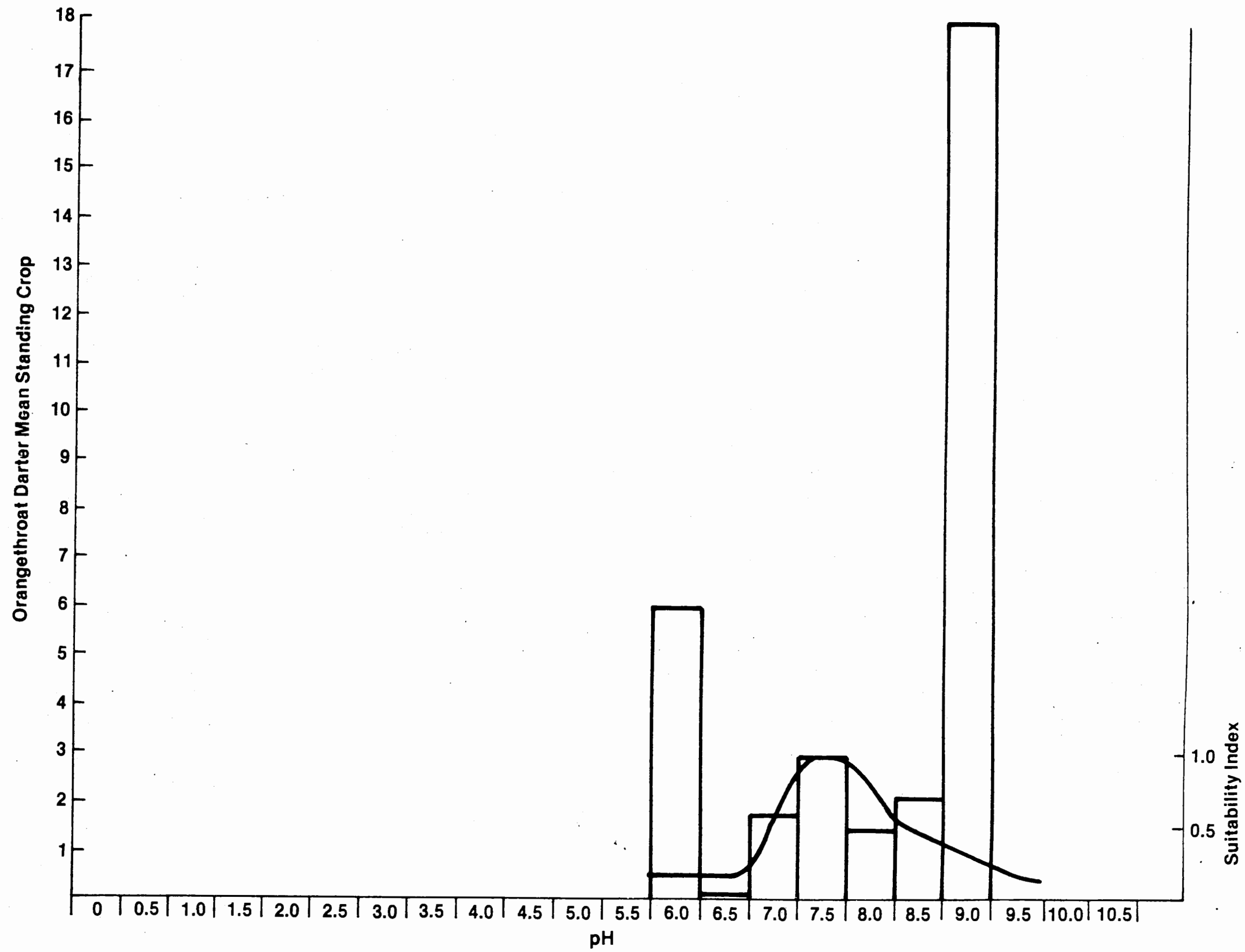


Figure 52. Relationship between orangethroat darter mean standing crop (kg/ha) and pH.

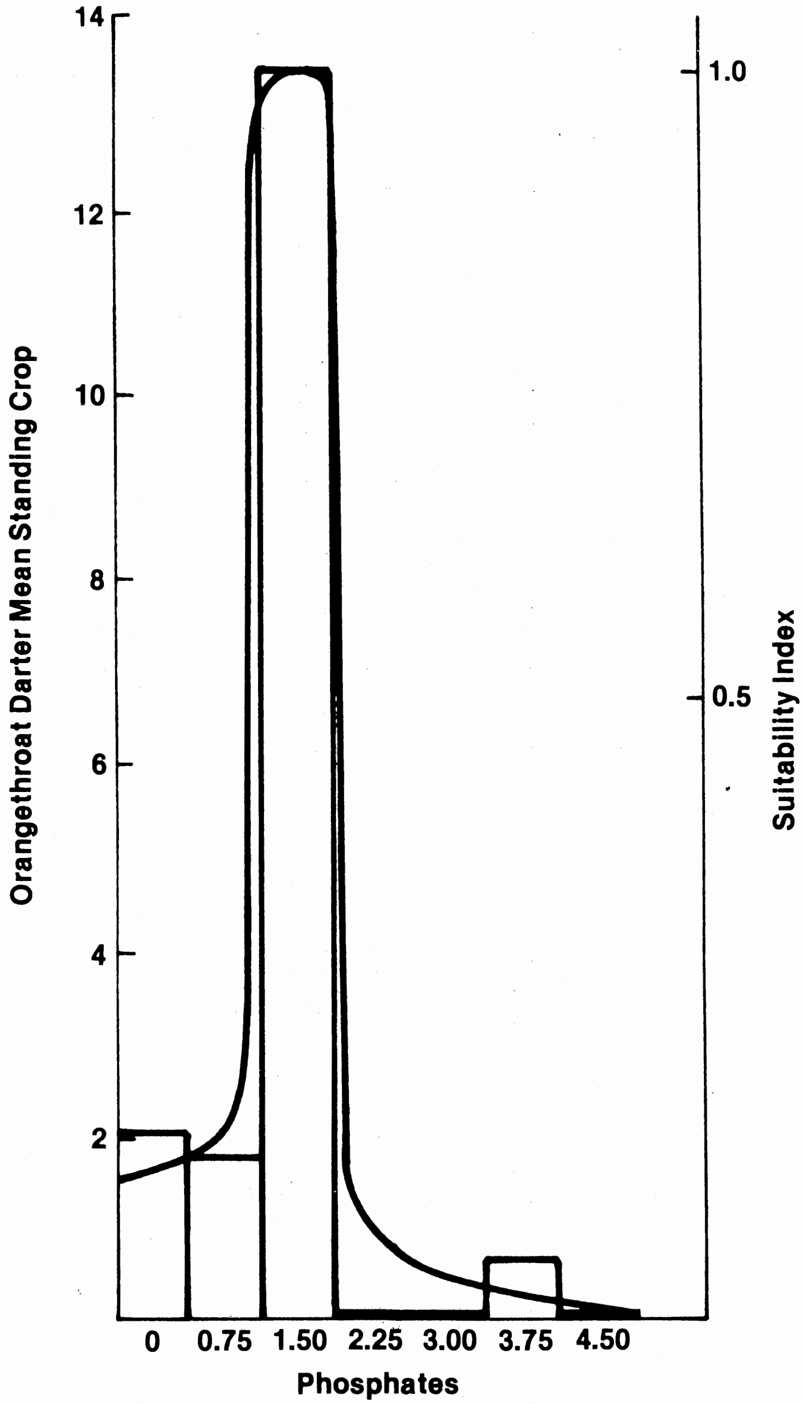


Figure 53. Relationship between orangethroat darter mean standing crop (kg/ha) and phosphates (mg/l).

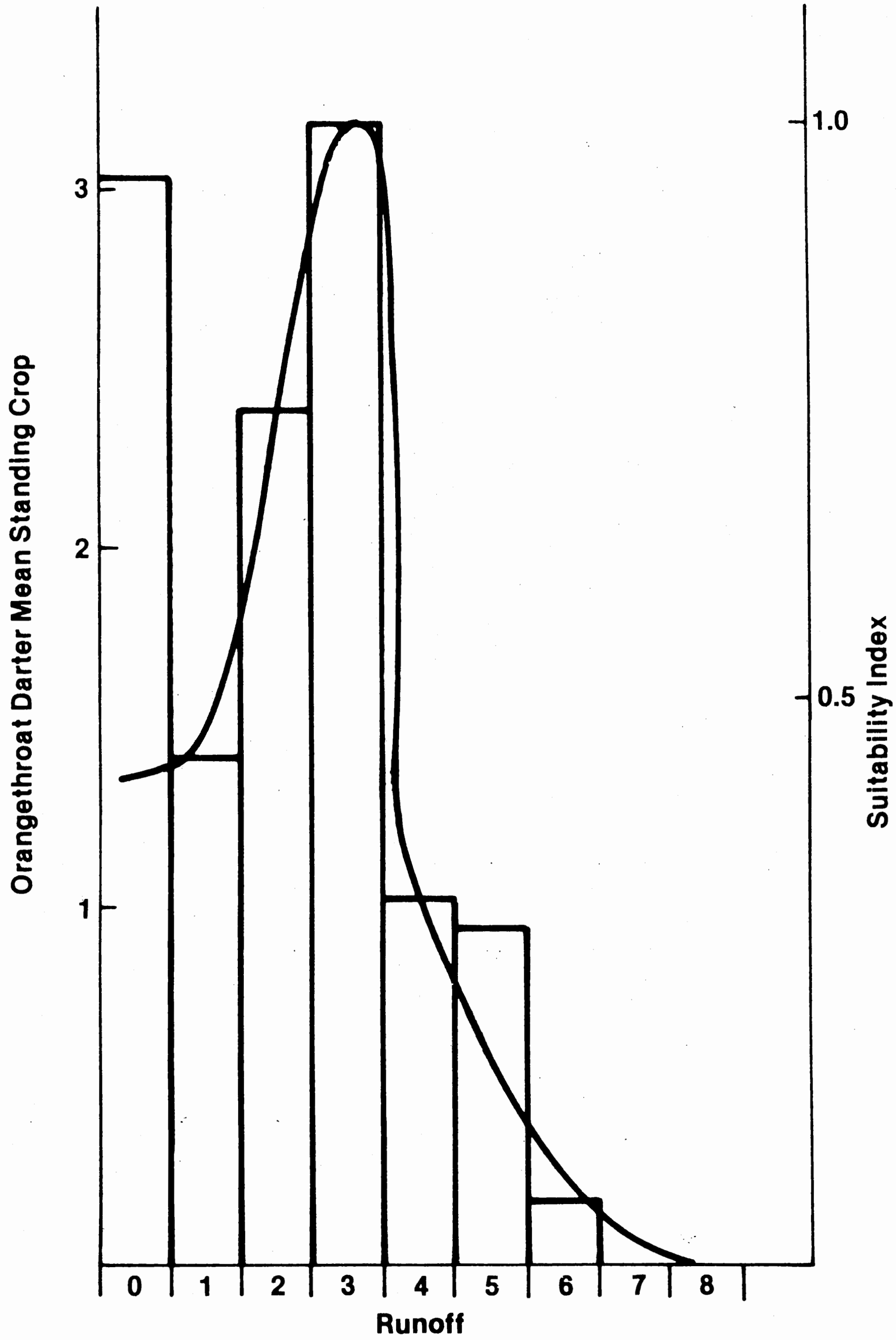


Figure 54. Relationship between orangethroat darter mean standing crop (kg/ha) and runoff (in/yr).

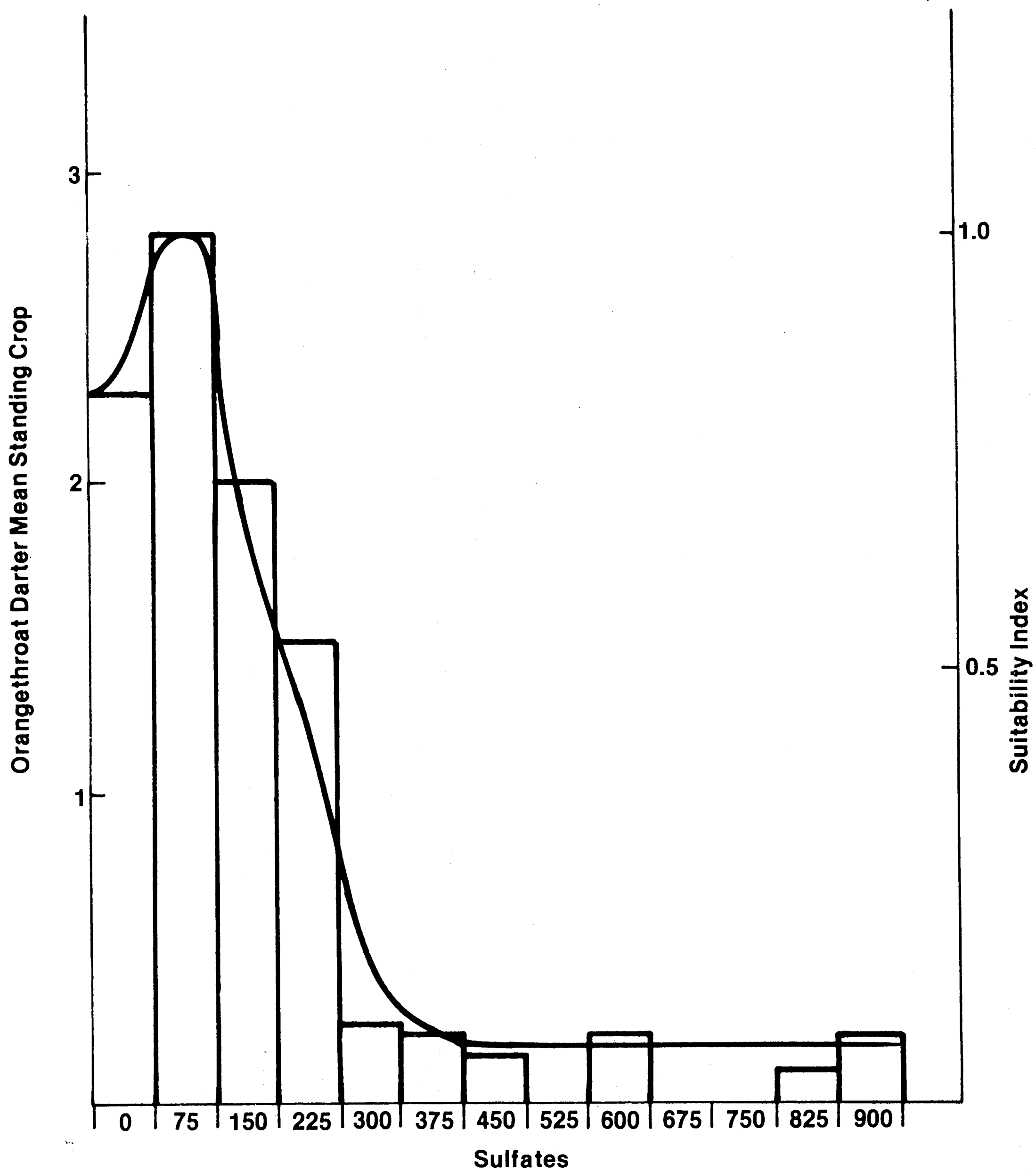


Figure 55. Relationship between orangethroat darter mean standing crop (kg/ha) and sulfates (mg/l).

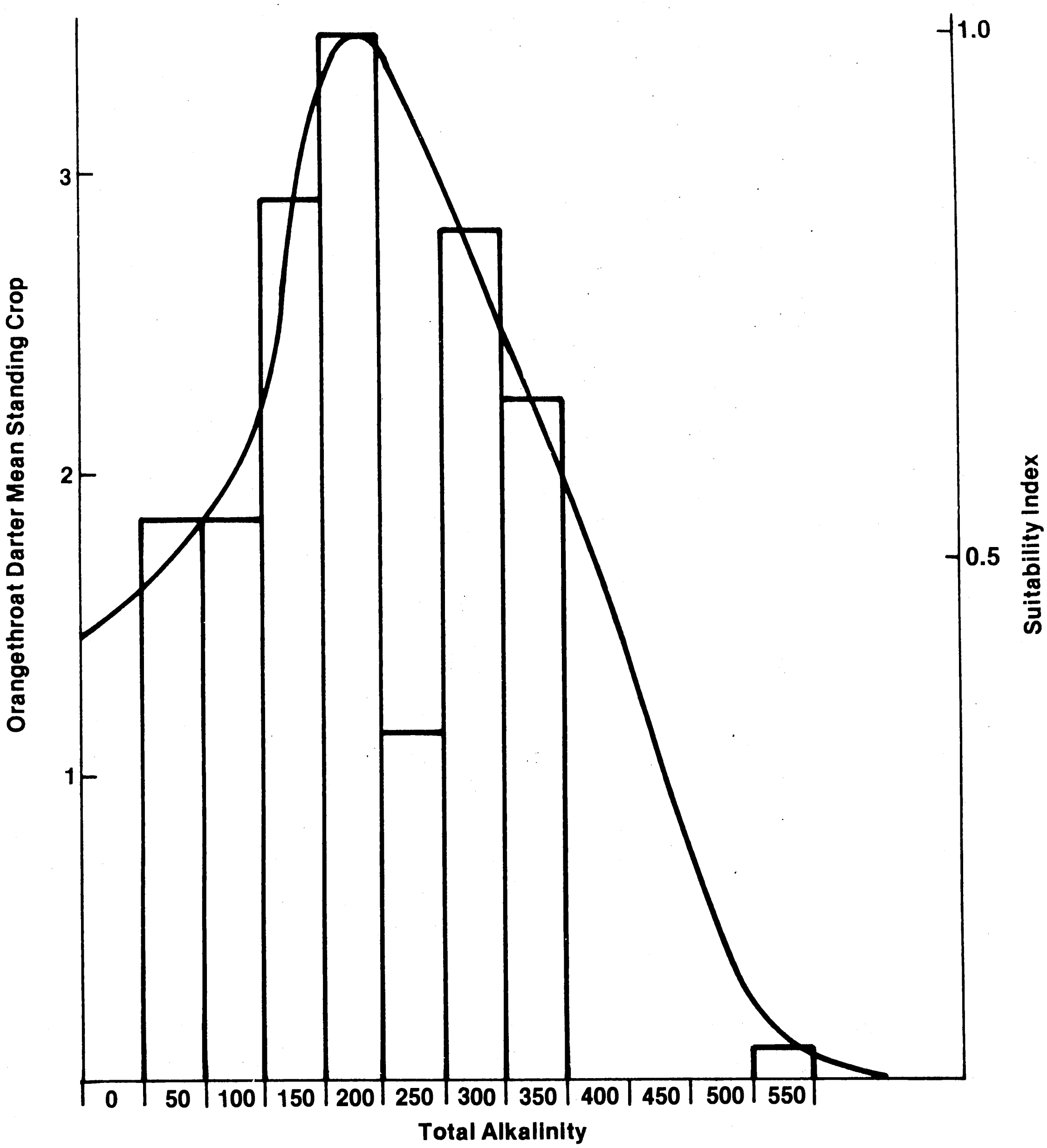


Figure 56. Relationship between orangethroat darter mean standing crop (kg/ha) and total alkalinity (mg/l).

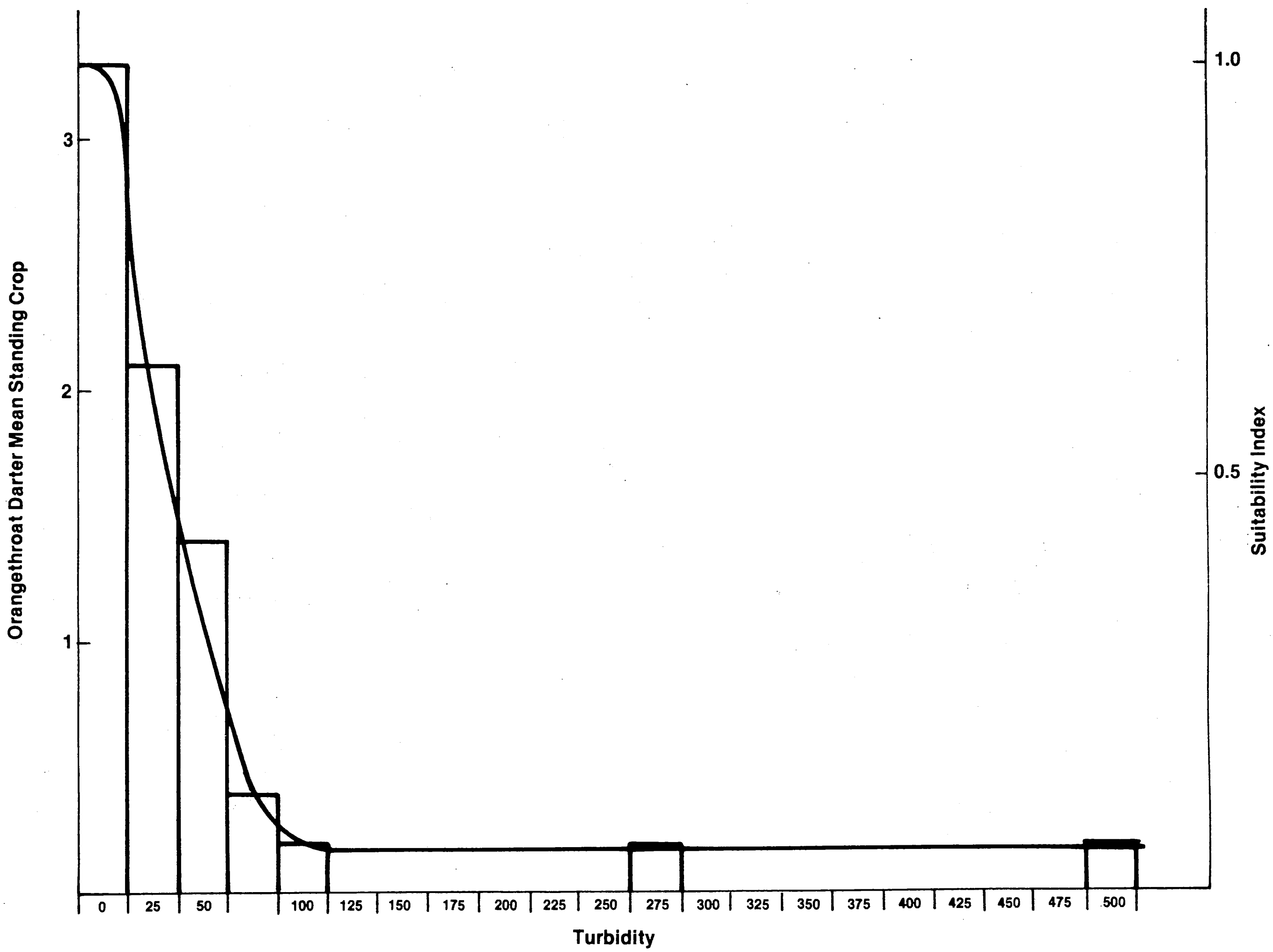


Figure 57. Relationship between orangethroat darter mean standing crop (kg/ha) and turbidity (JTU's).

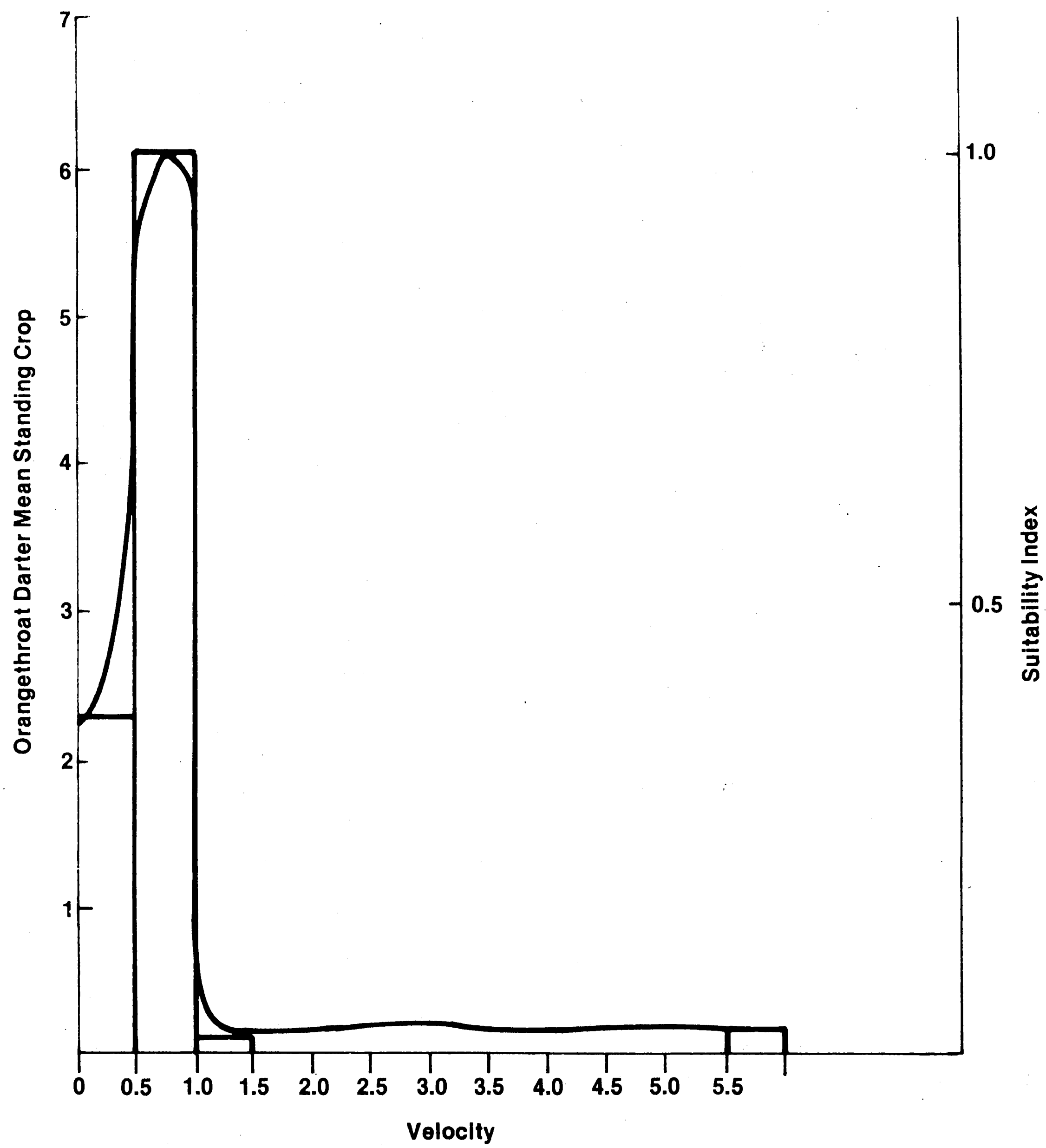


Figure 58. Relationship between orangethroat darter mean standing crop (kg/ha) and velocity (m/s).

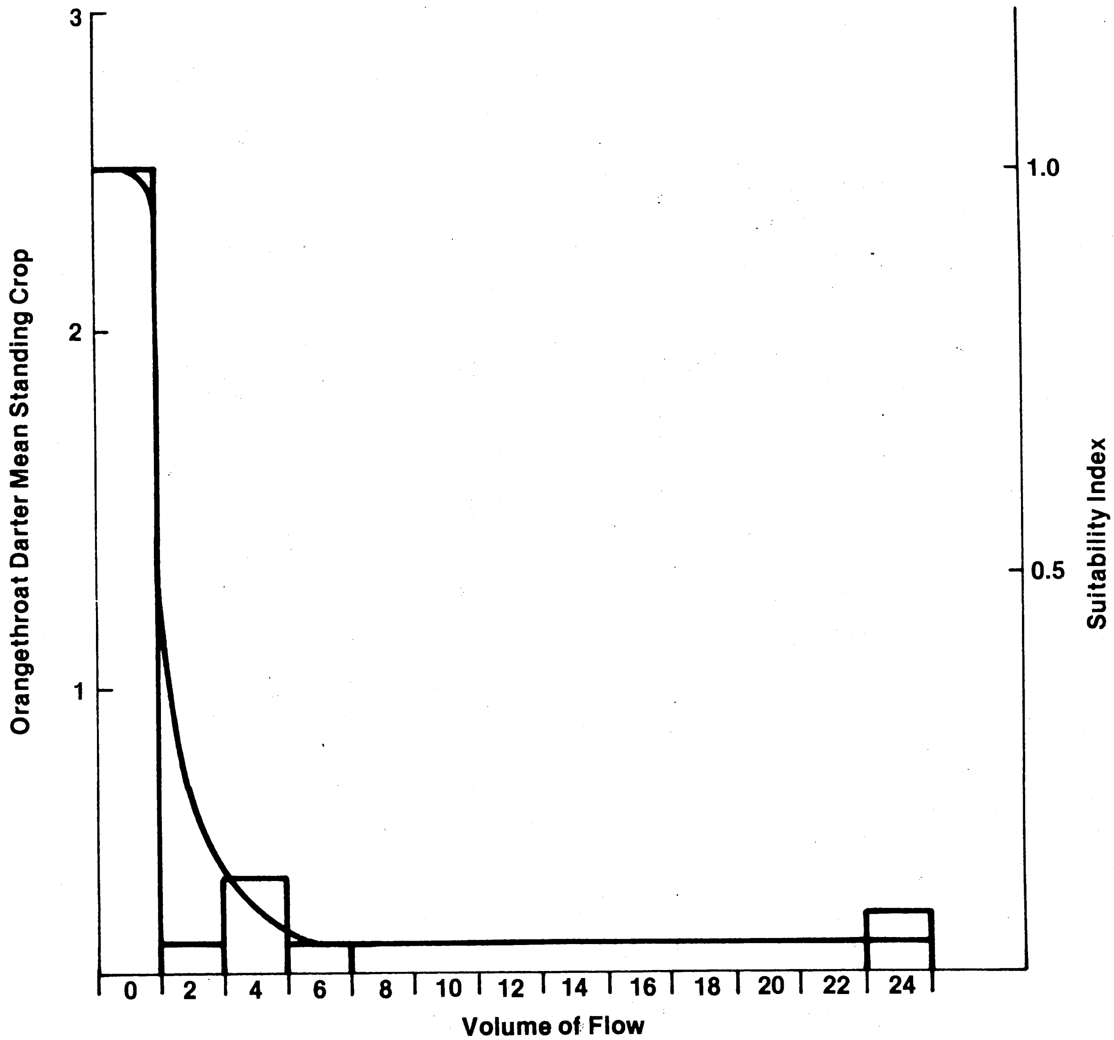


Figure 59. Relationship between orangethroat darter mean standing crop (kg/ha) and volume of flow ($m^3/s$).

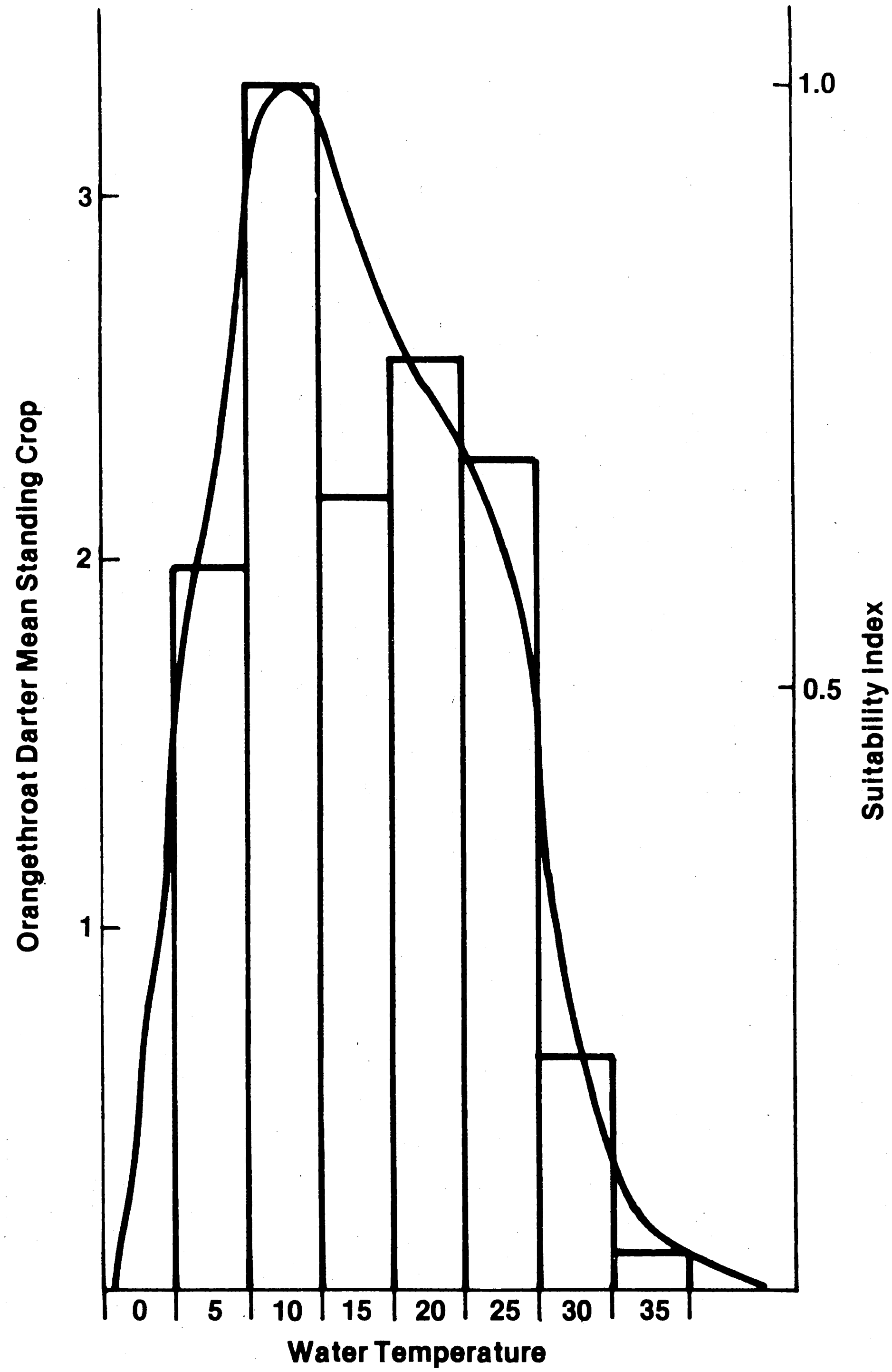


Figure 60. Relationship between orangethroat darter mean standing crop (kg/ha) and water temperature (C).

APPENDIX D

CENTRAL STONEROLLER SUITABILITY CURVES

(INTERVAL RANGES, MEANS, AND N VALUES

GIVEN IN APPENDIX I)

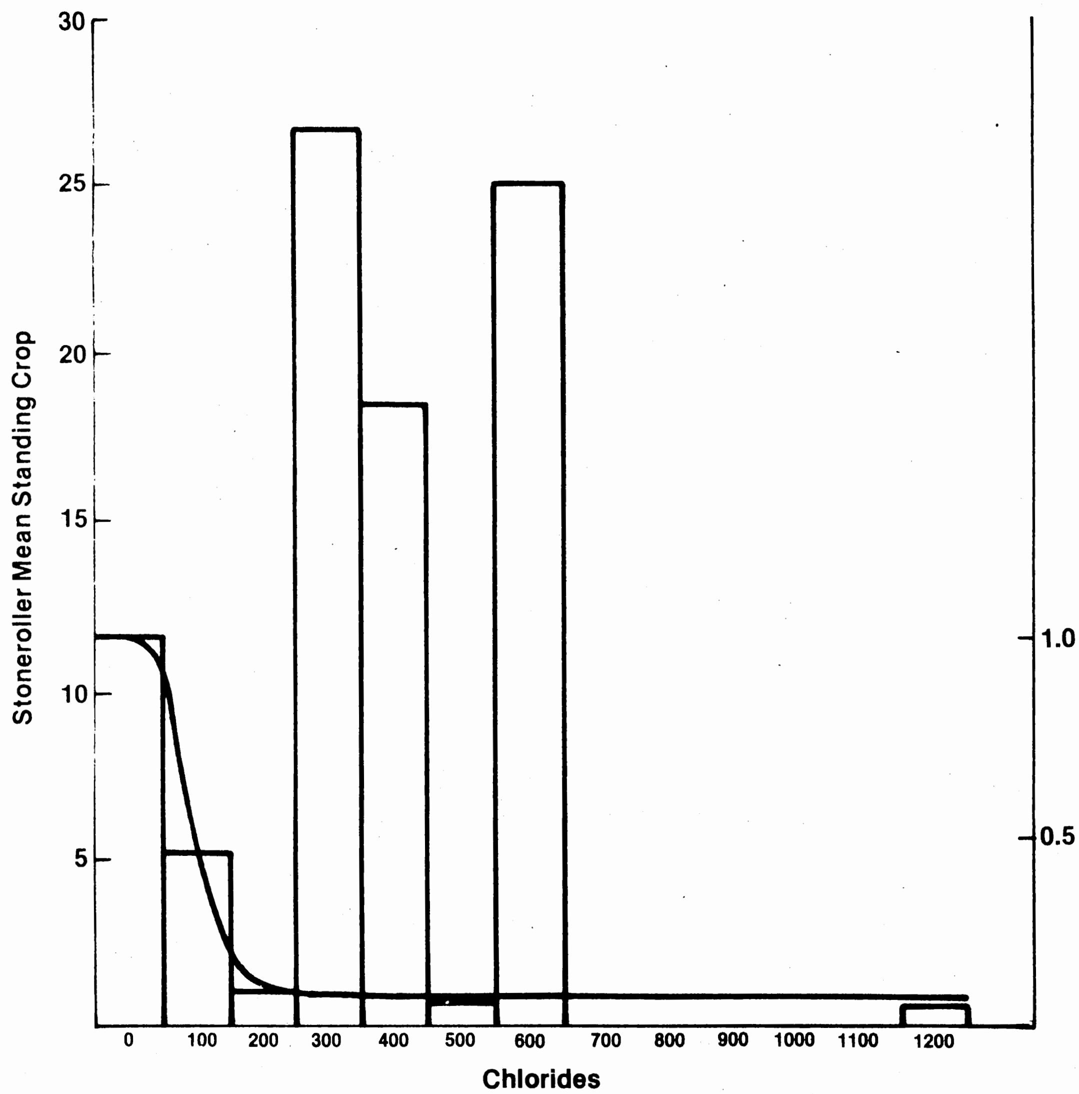


Figure 61. Relationship between central stoneroller mean standing crop (kg/ha) and chlorides (mg/l).

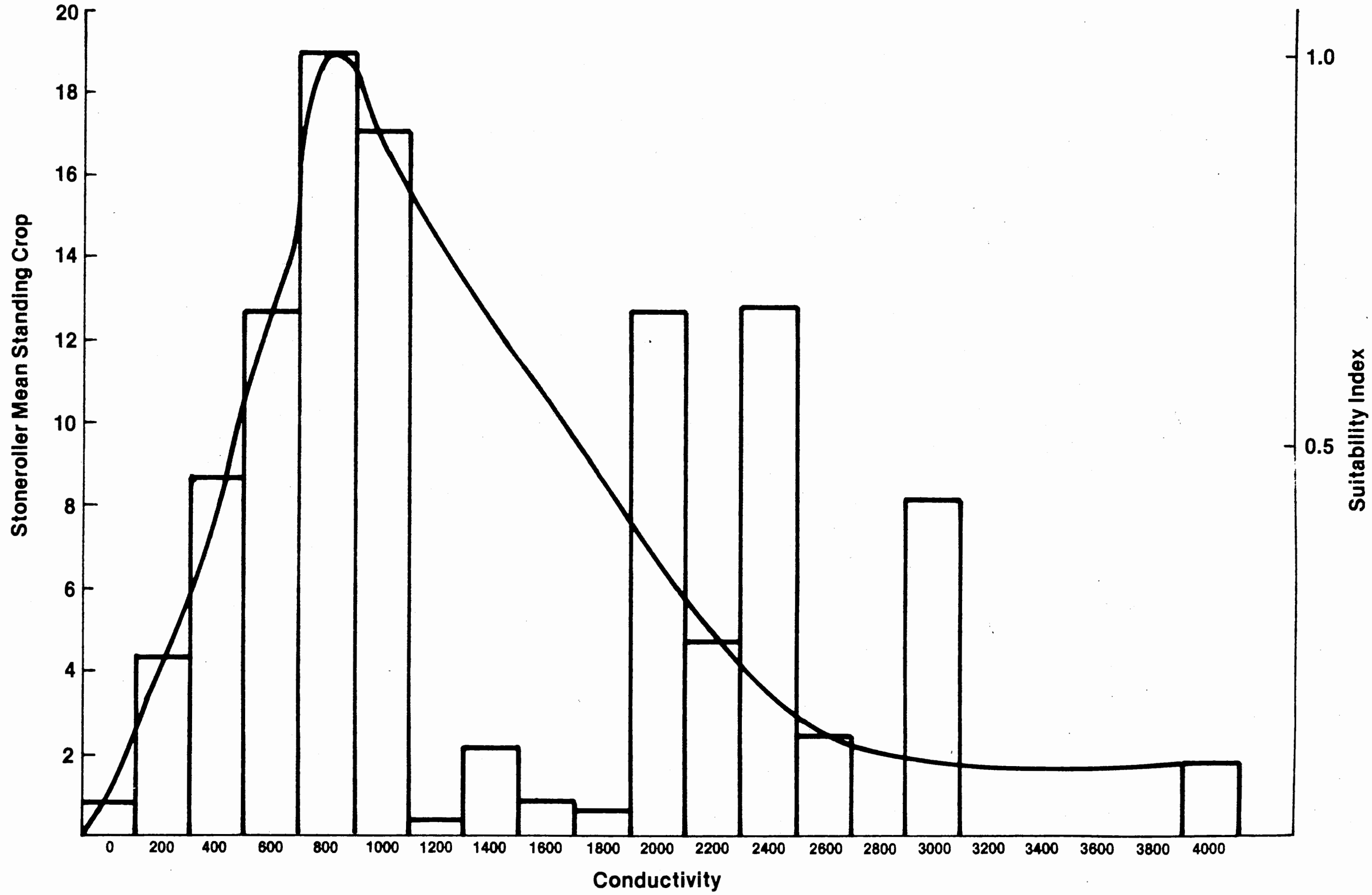


Figure 62. Relationship between central stoneroller mean standing crop (kg/ha) and conductivity (µmhos/cm).

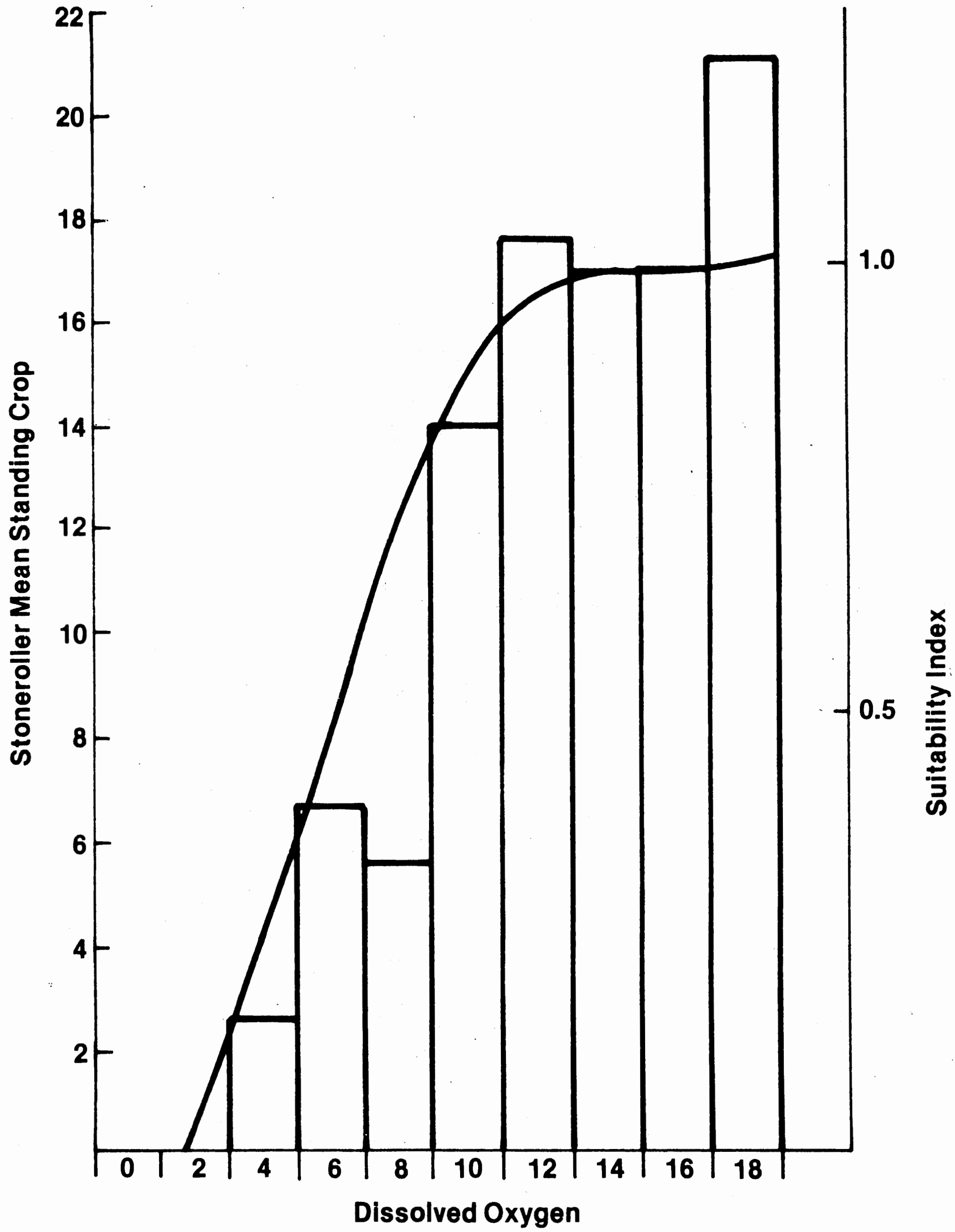


Figure 63. Relationship between central stoneroller mean standing crop (kg/ha) and dissolved oxygen (mg/l).

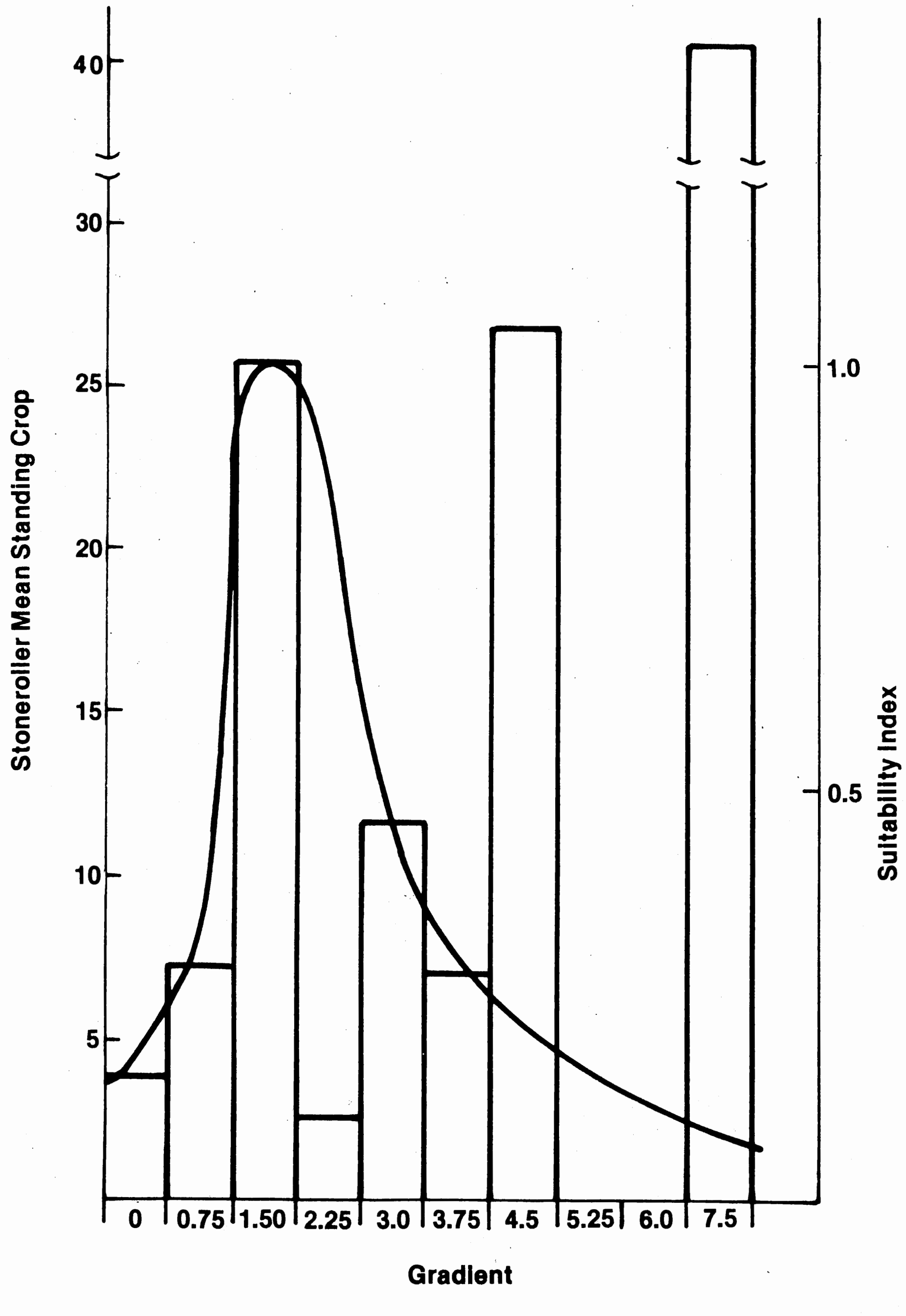


Figure 64. Relationship between central stoneroller mean standing crop (kg/ha) and gradient (m/km).

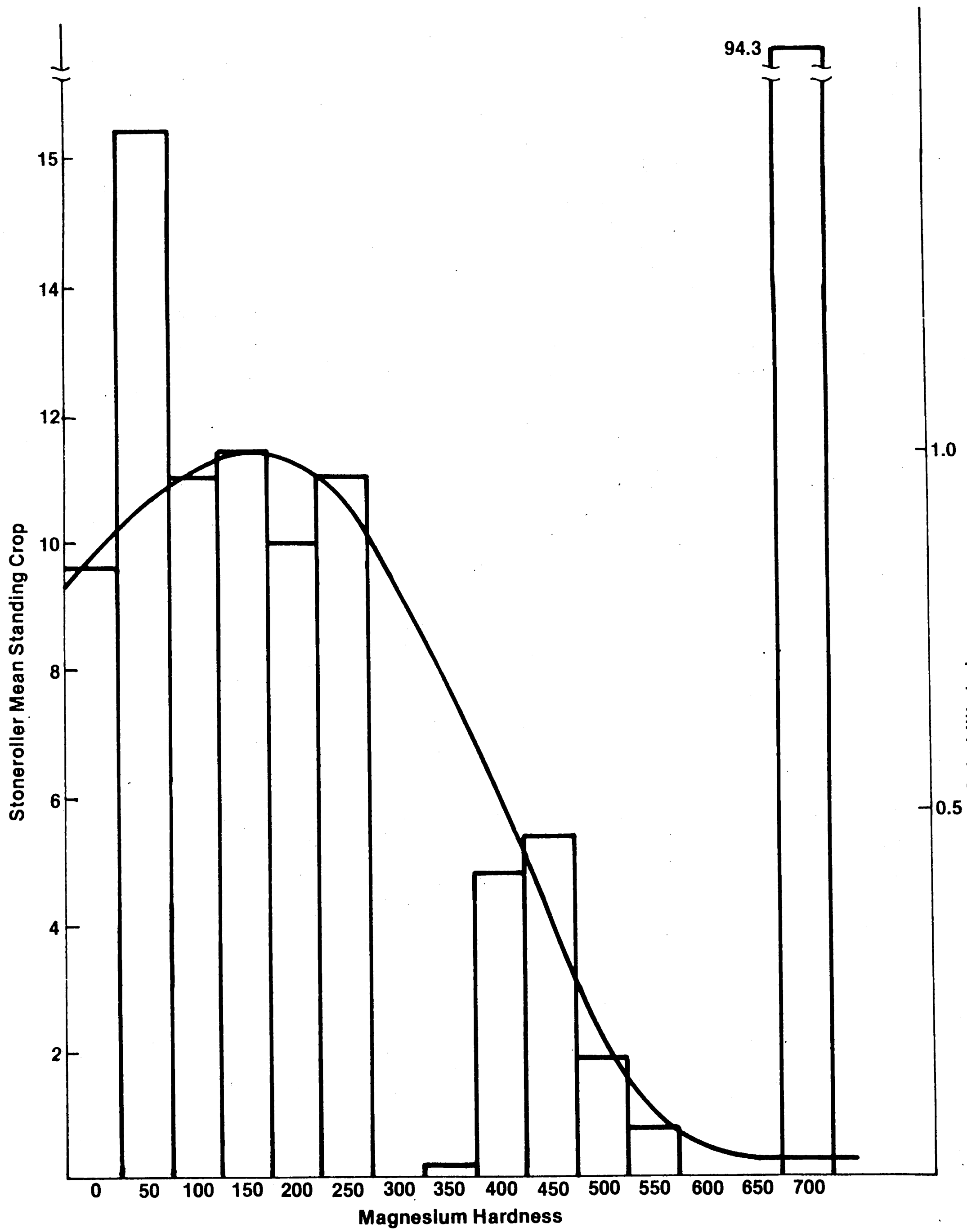


Figure 65. Relationship between central stoneroller mean standing crop (kg/ha) and magnesium hardness (mg/l).

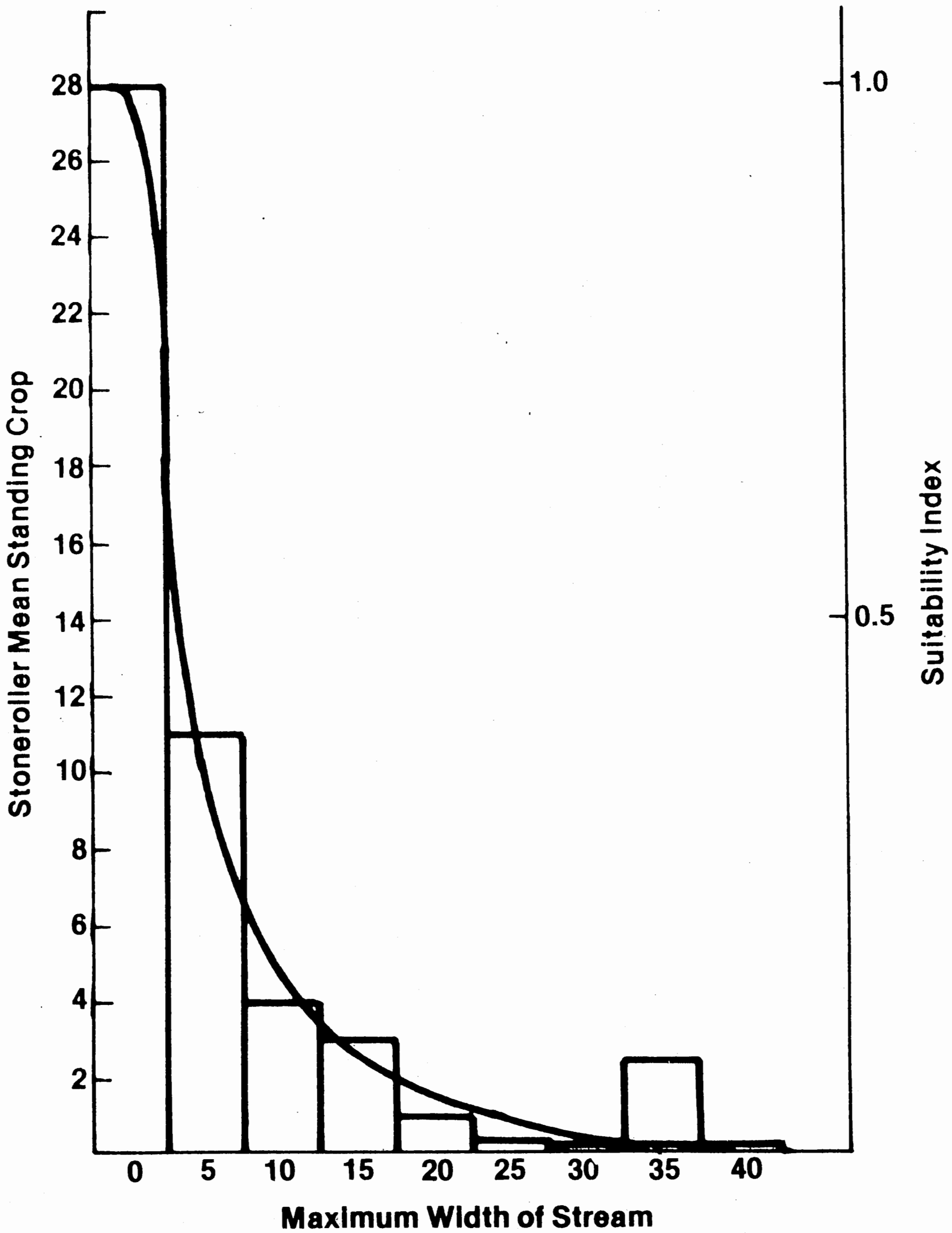


Figure 66. Relationship between central stoneroller mean standing crop (kg/ha) and maximum stream width (m).

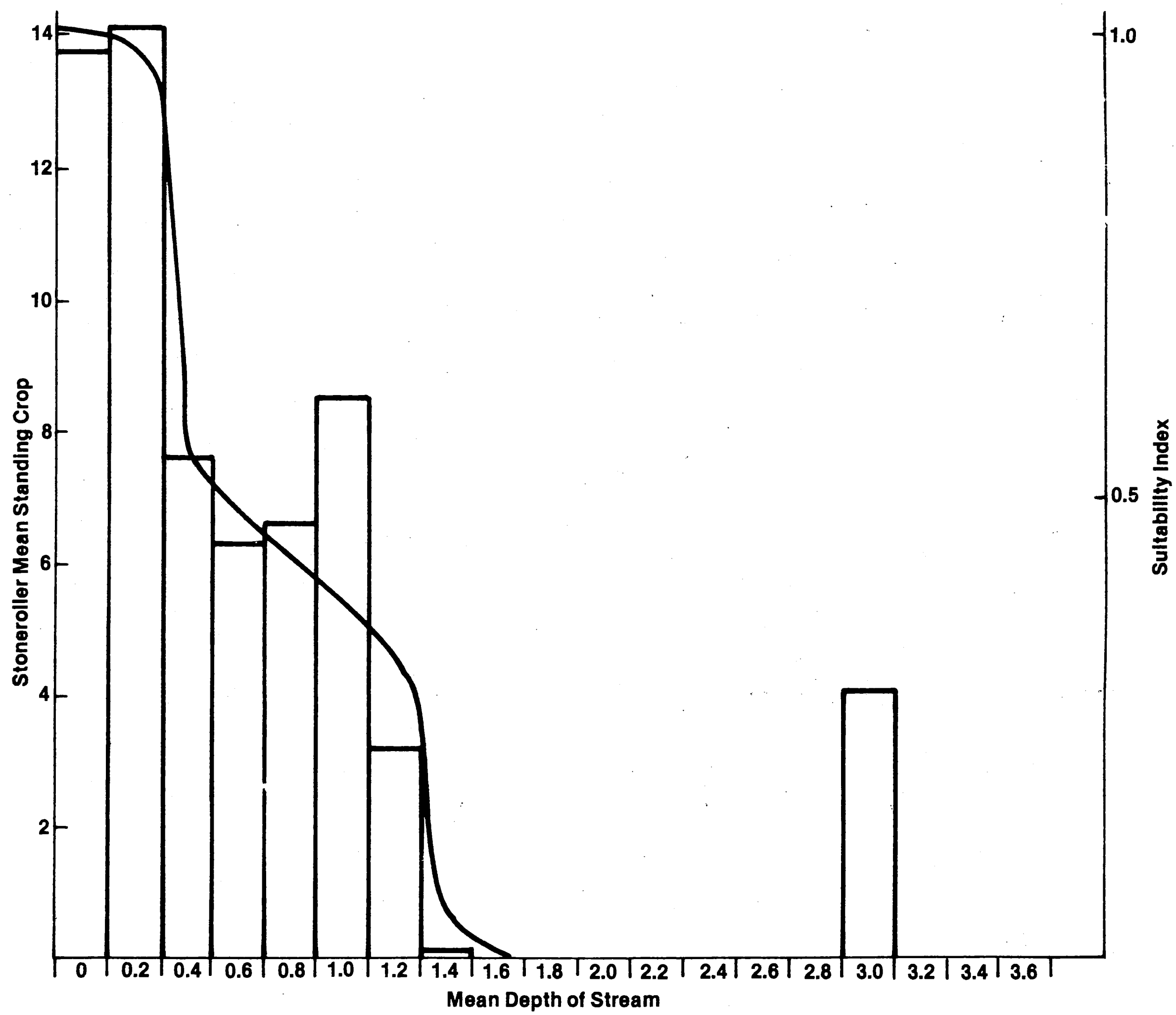


Figure 67. Relationship between central stoneroller mean standing crop (kg/ha) and mean stream depth (m).

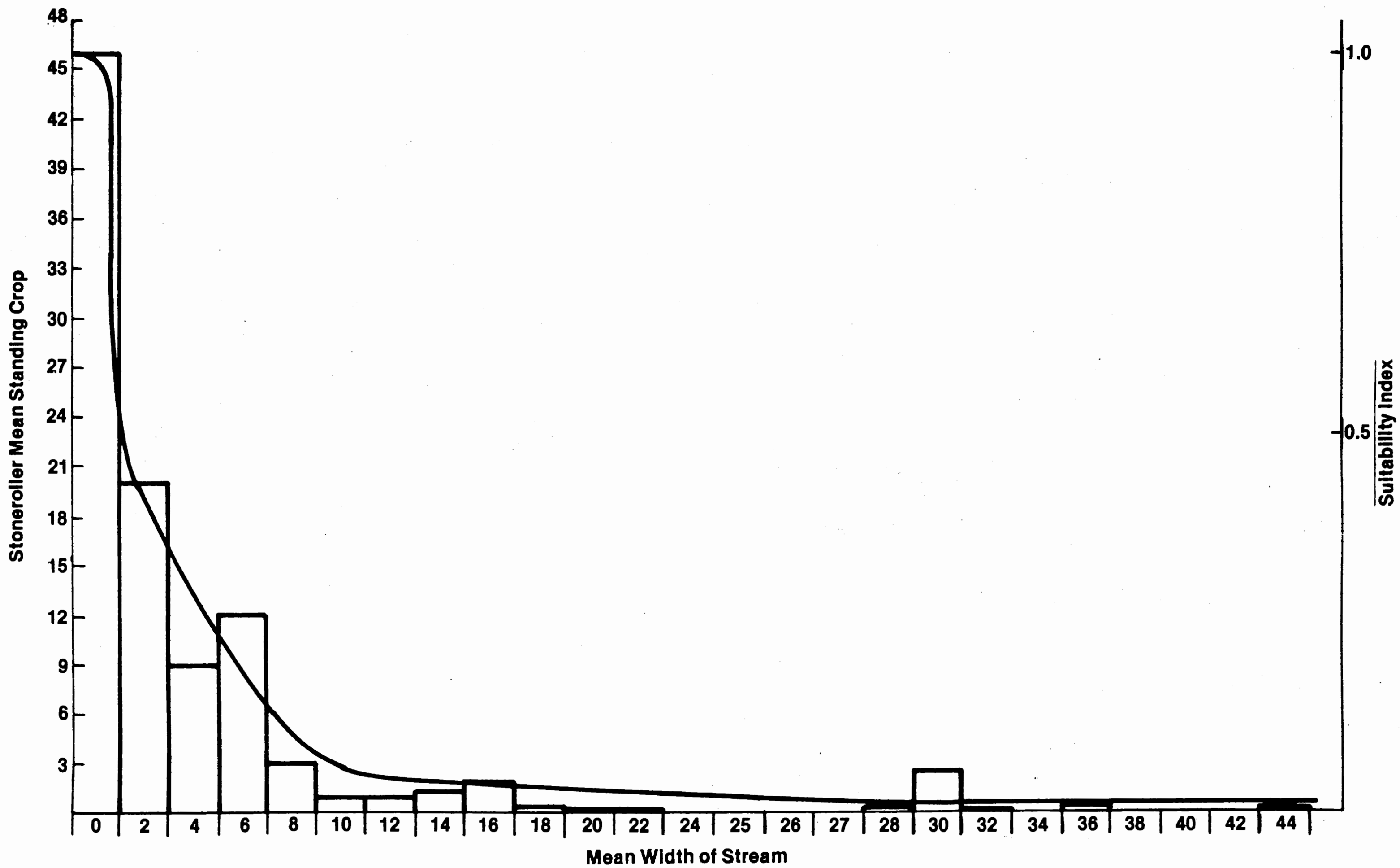


Figure 68. Relationship between central stoneroller mean standing crop (kg/ha) and mean stream width (m).

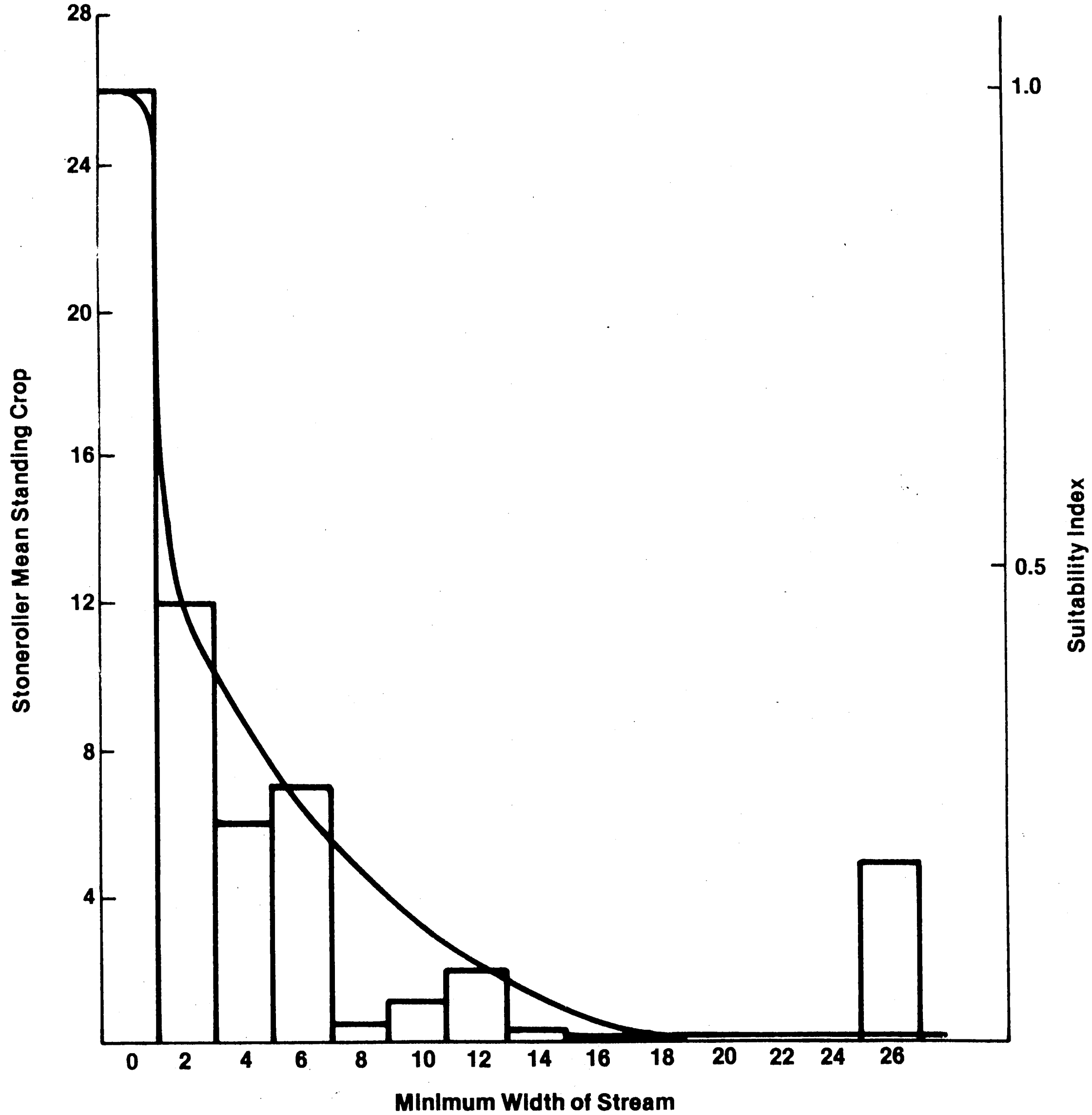


Figure 69. Relationship between central stoneroller mean standing crop (kg/ha) and minimum stream width (m).

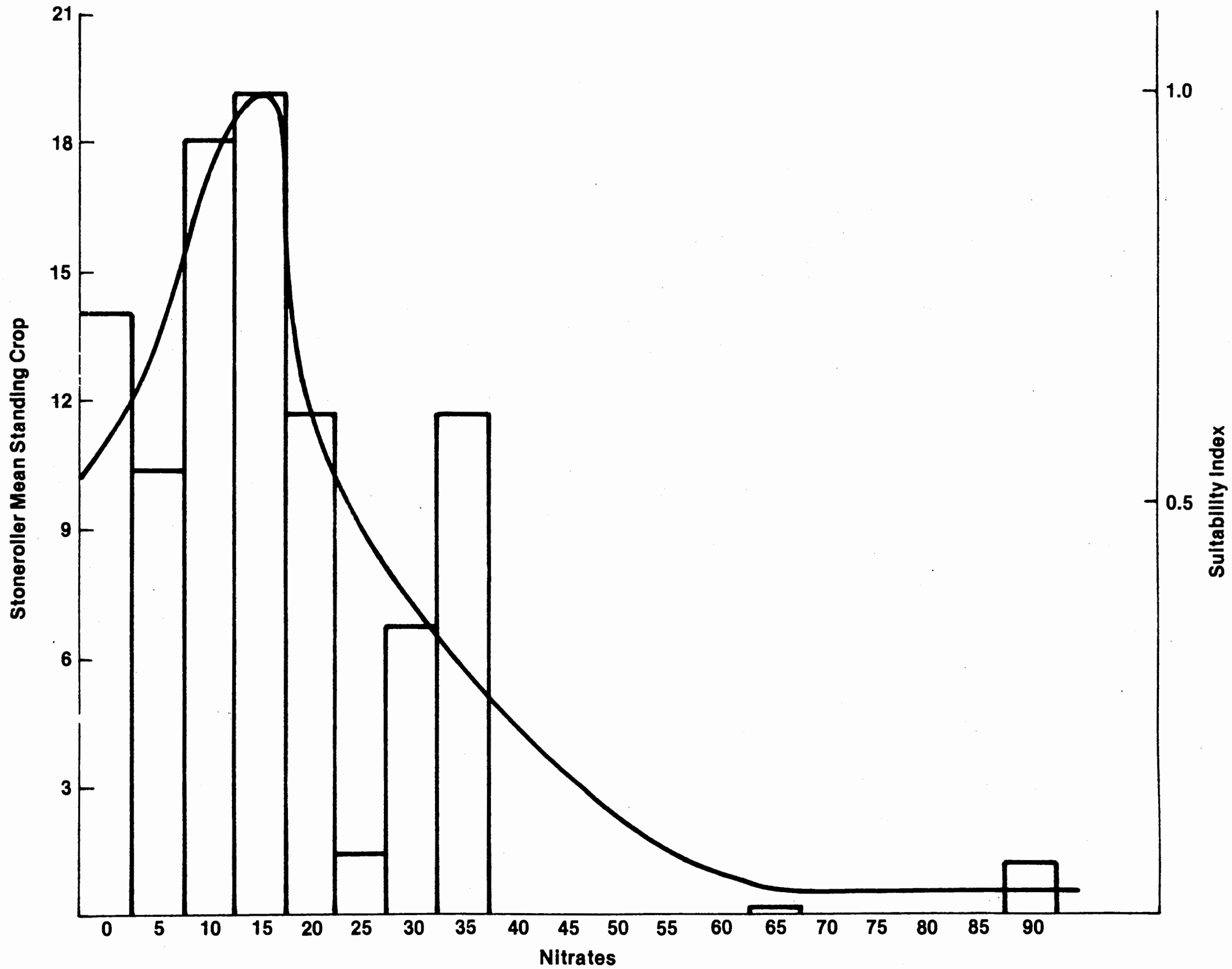


Figure 70. Relationship between central stoneroller mean standing crop (kg/ha) and nitrates (mg/l).

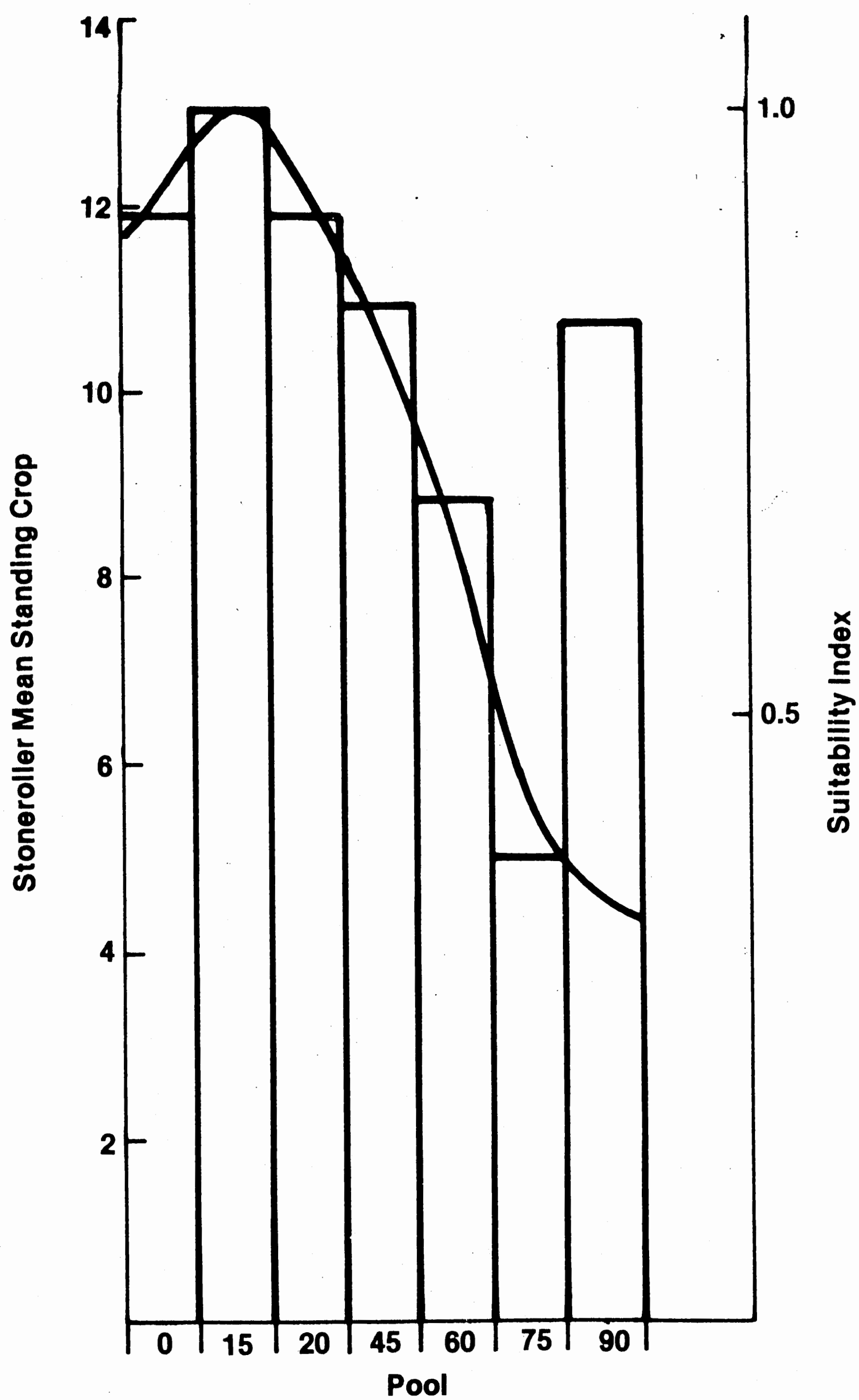


Figure 71. Relationship between central stoneroller mean standing crop (kg/ha) and percent pool.

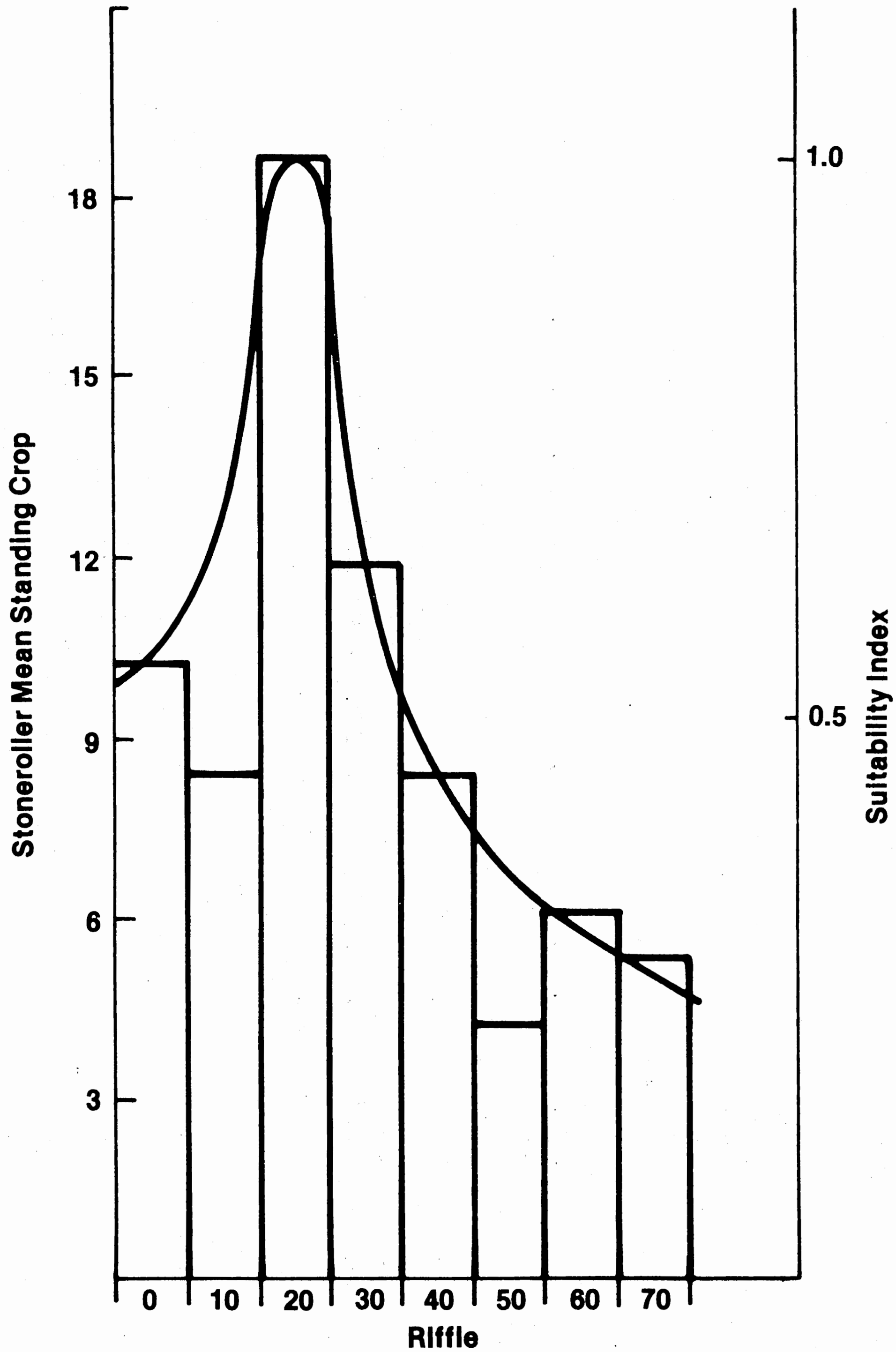


Figure 72. Relationship between central stoneroller mean standing crop (kg/ha) and percent riffle.

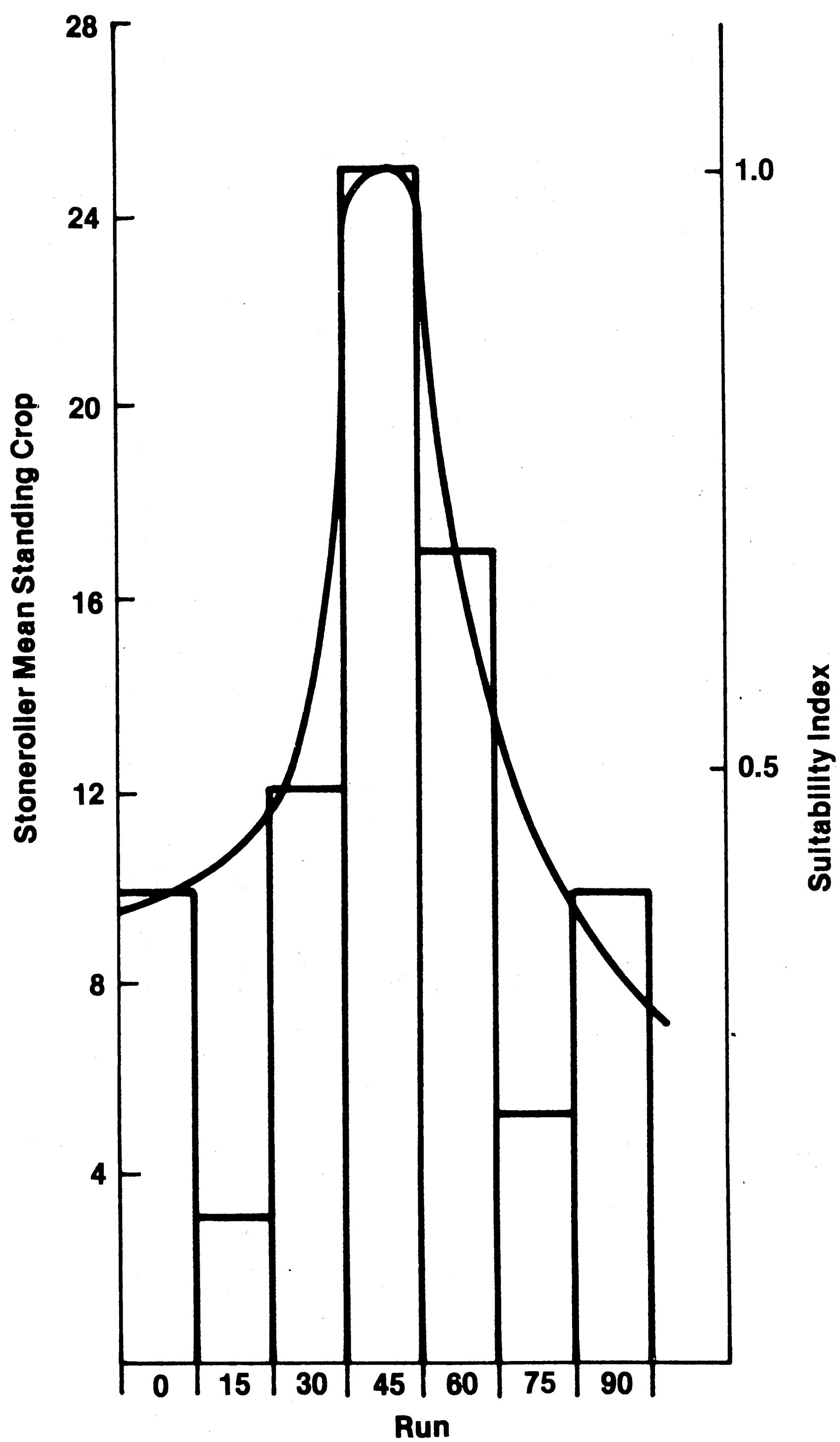


Figure 73. Relationship between central stoneroller mean standing crop (kg/ha) and percent run.

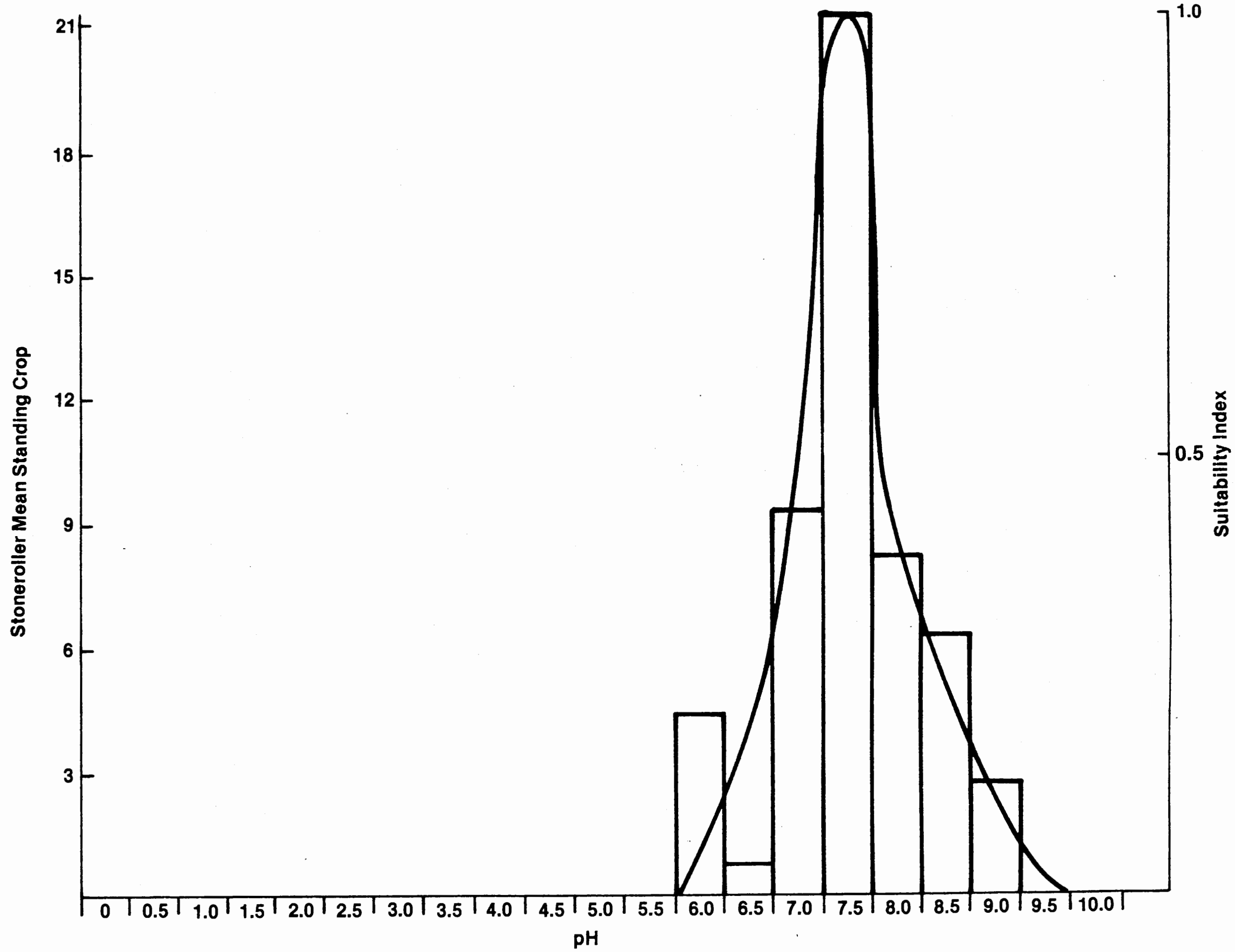


Figure 74. Relationship between central stoneroller mean standing crop (kg/ha) and pH.

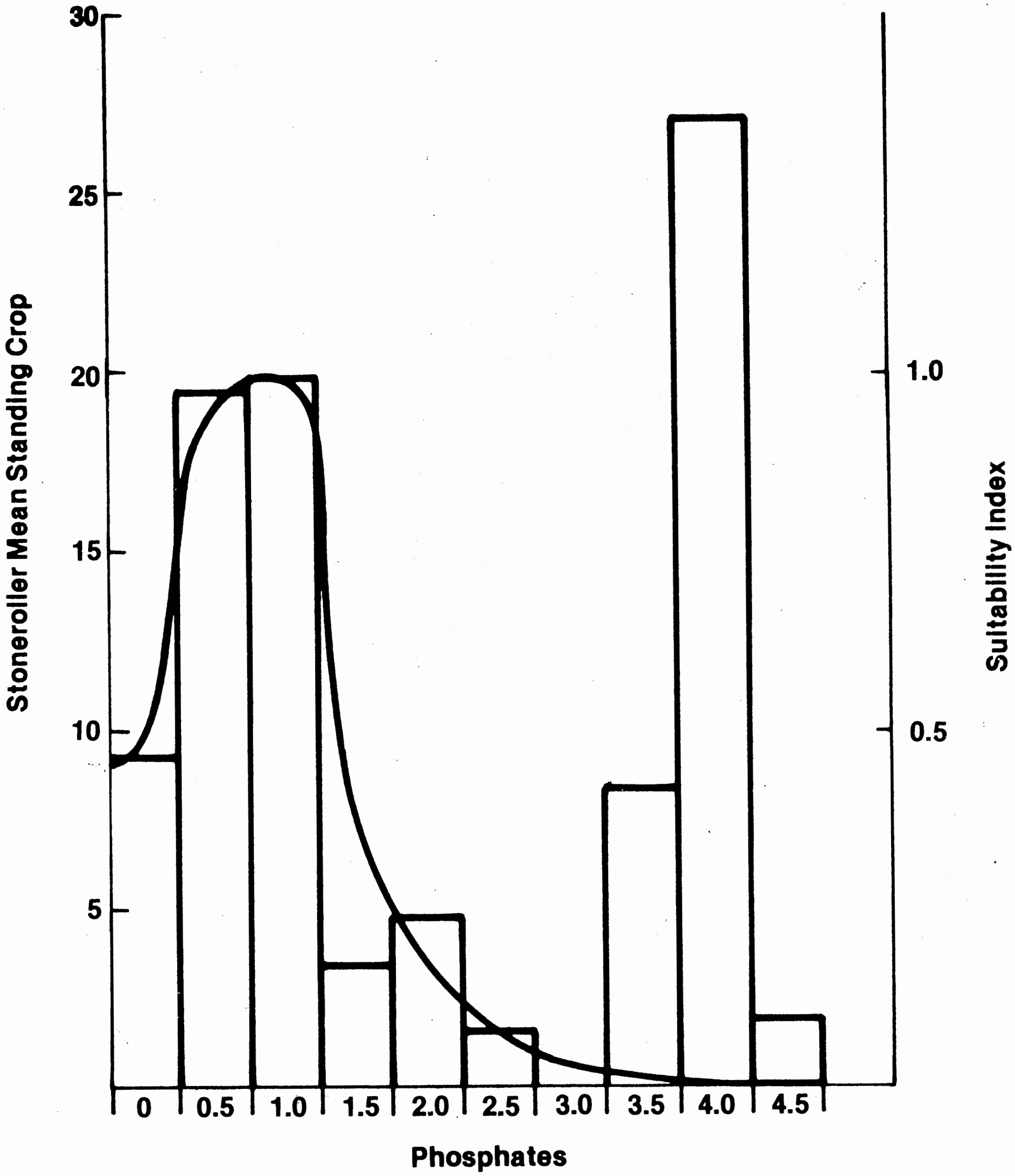


Figure 75. Relationship between central stoneroller mean standing crop (kg/ha) and phosphates (mg/l).

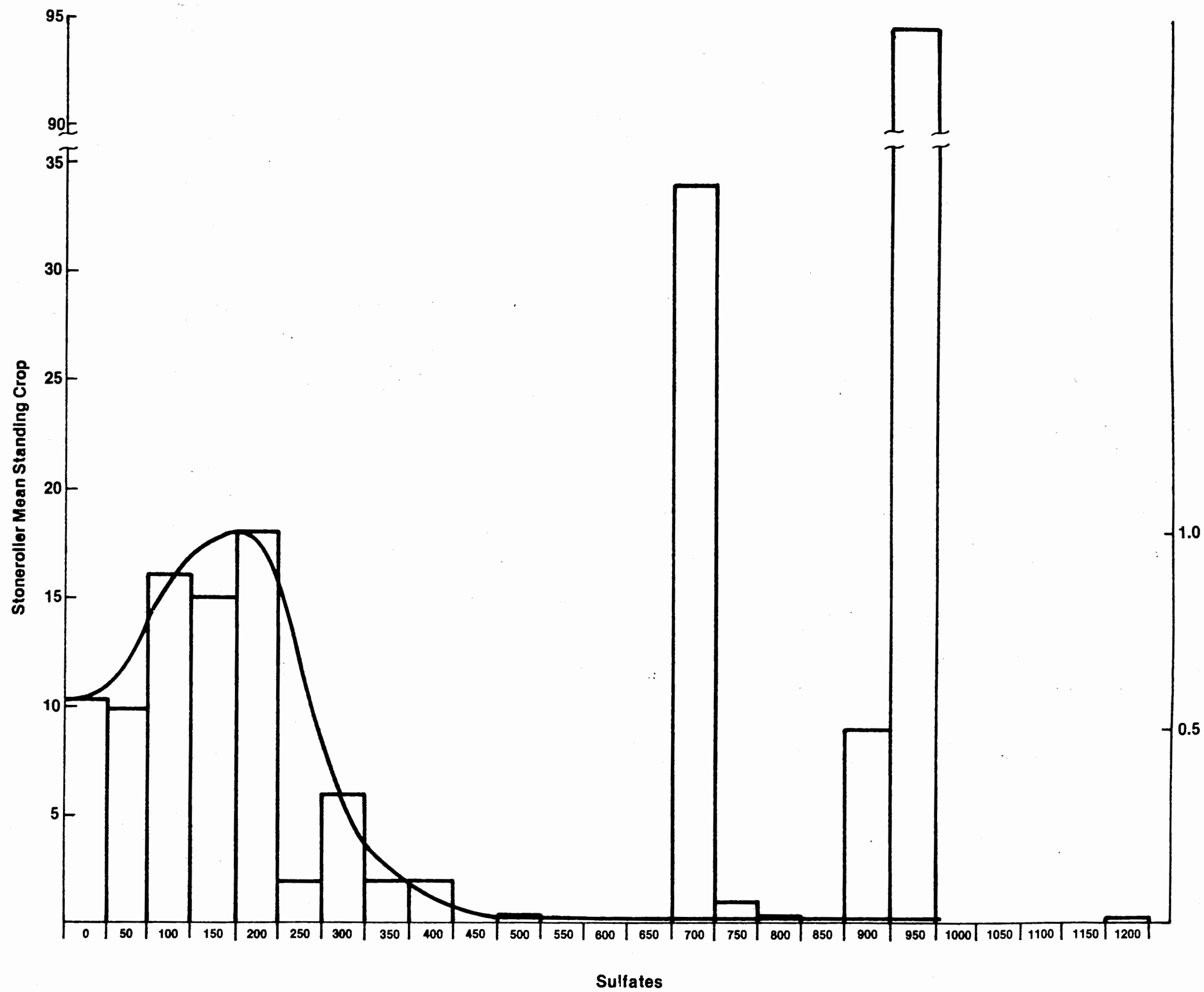


Figure 76. Relationship between central stoneroller mean standing crop (kg/ha) and sulfates (mg/l).

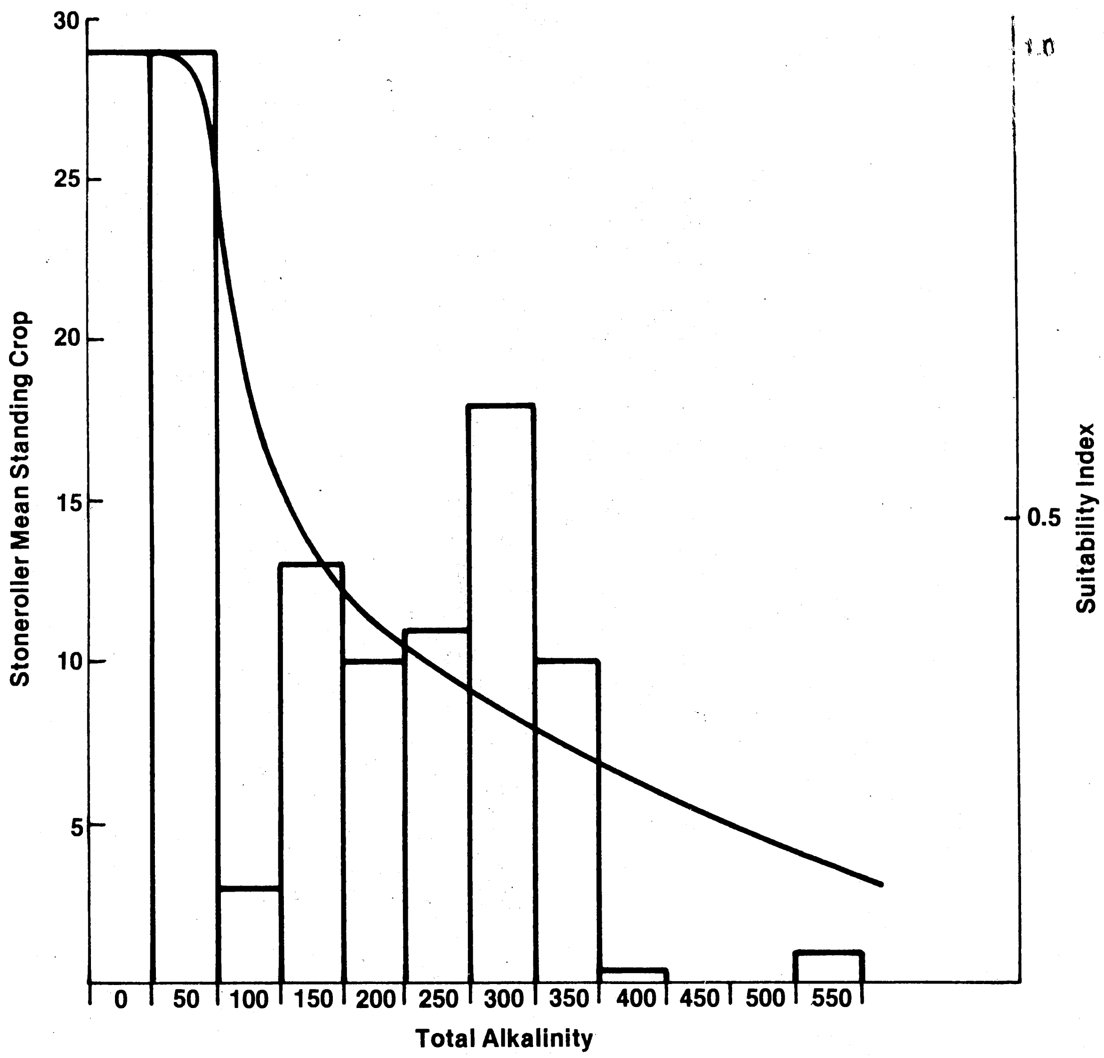


Figure 77. Relationship between central stoneroller mean standing crop (kg/ha) and total alkalinity (mg/l).

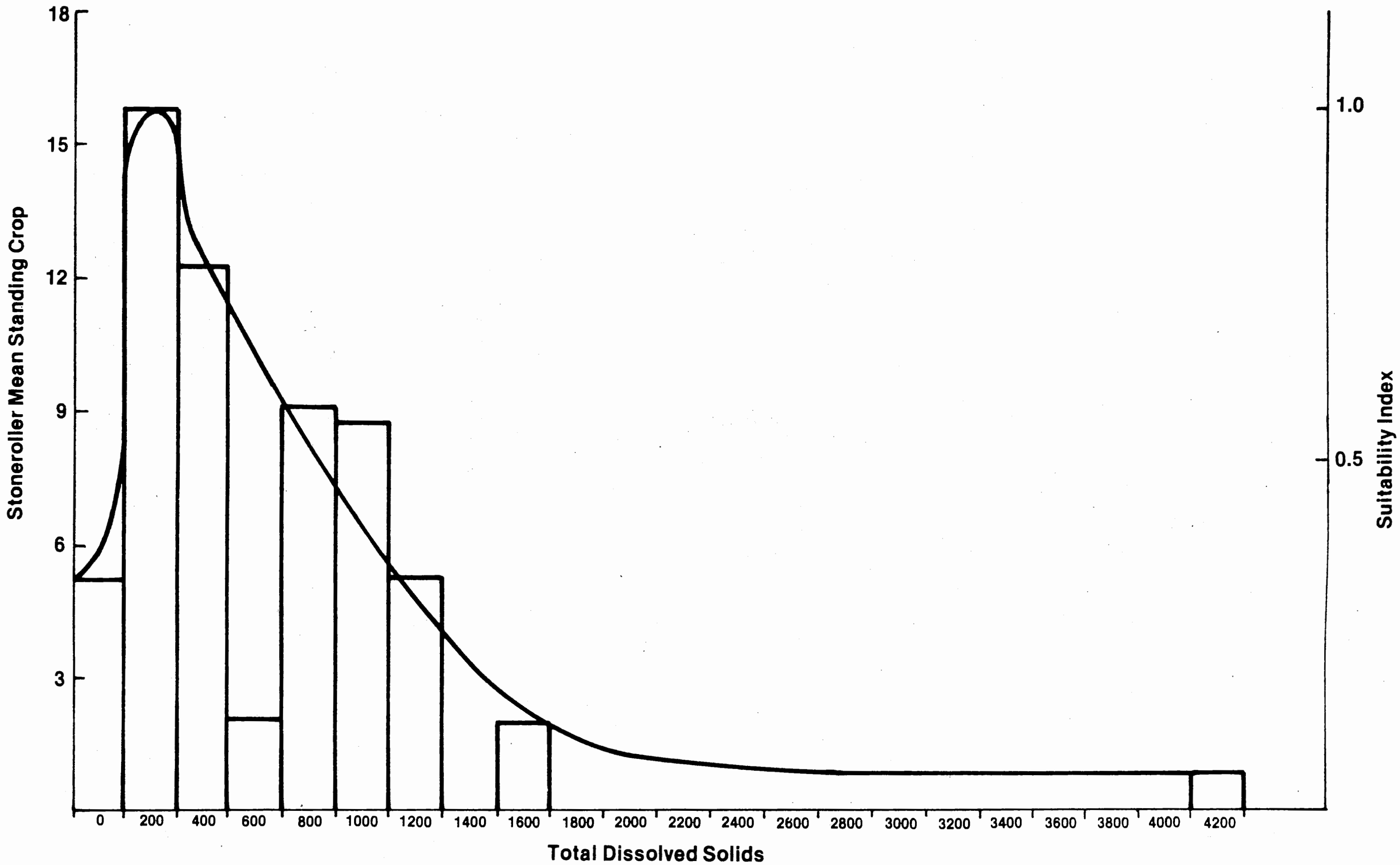


Figure 78. Relationship between central stoneroller mean standing crop (kg/ha) and total dissolved solids (mg/l).

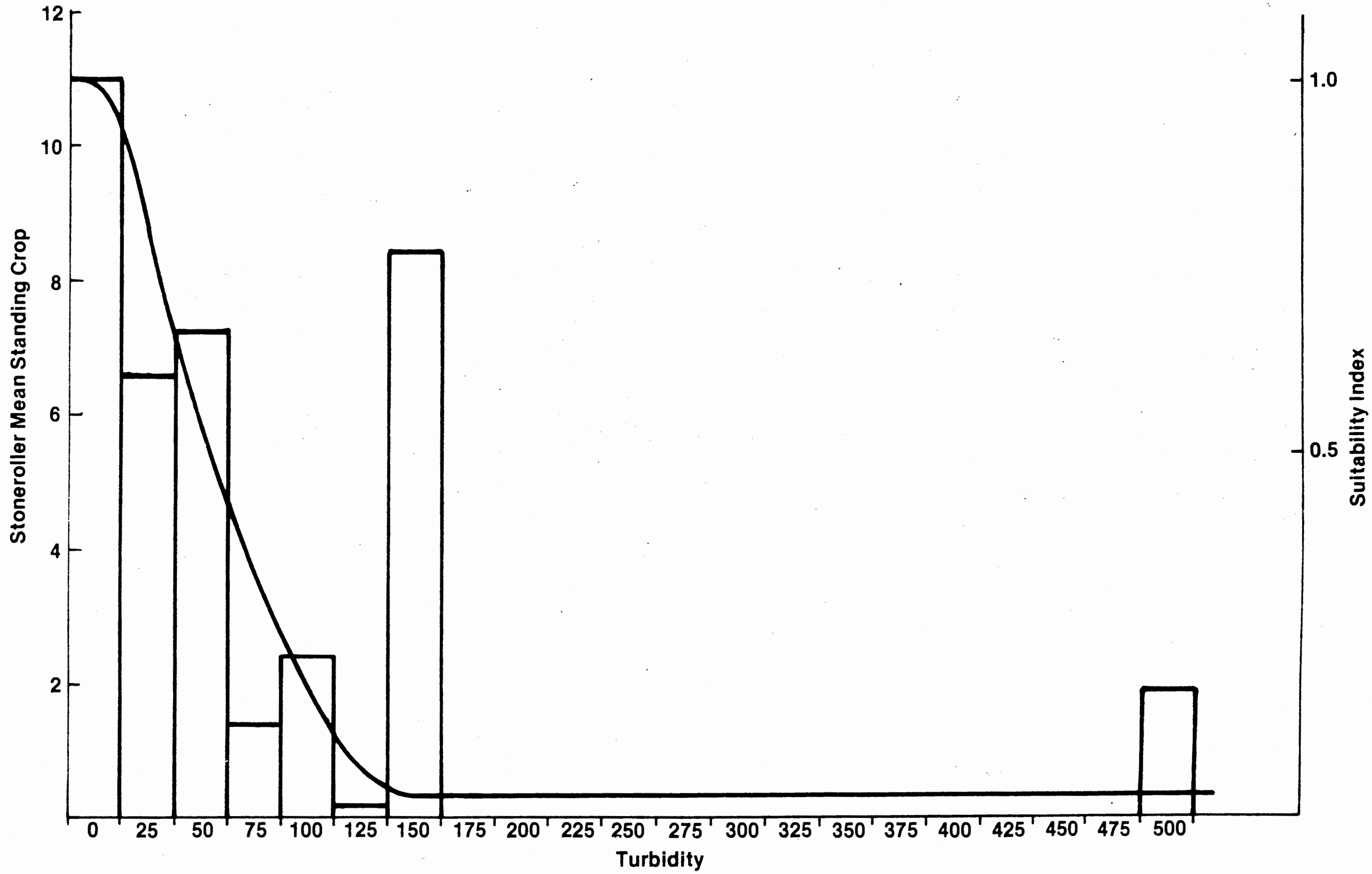


Figure 79. Relationship between central stoneroller mean standing crop (kg/ha) and turbidity (JTU's).

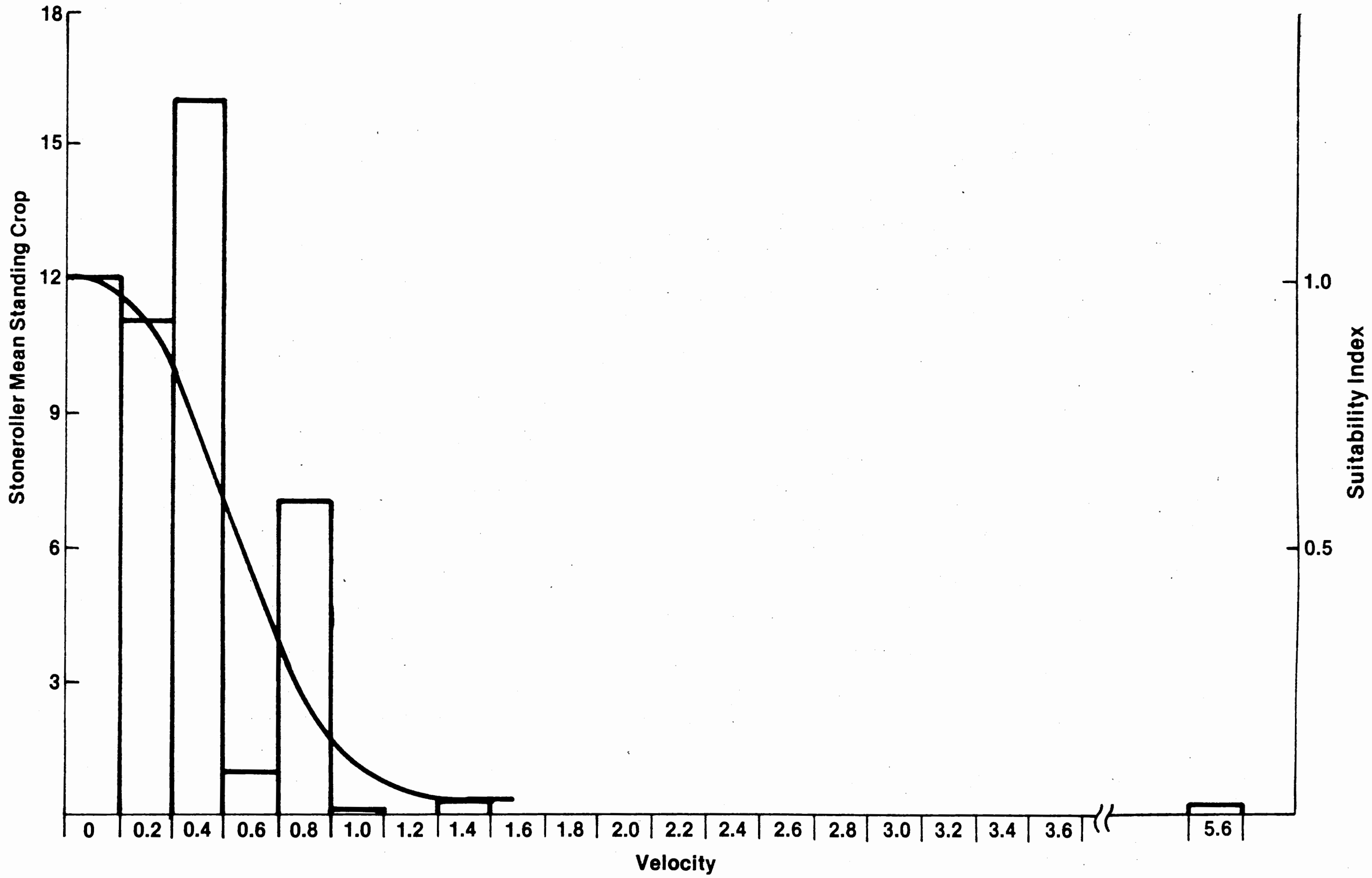


Figure 80. Relationship between central stoneroller mean standing crop (kg/ha) and velocity (m/s).

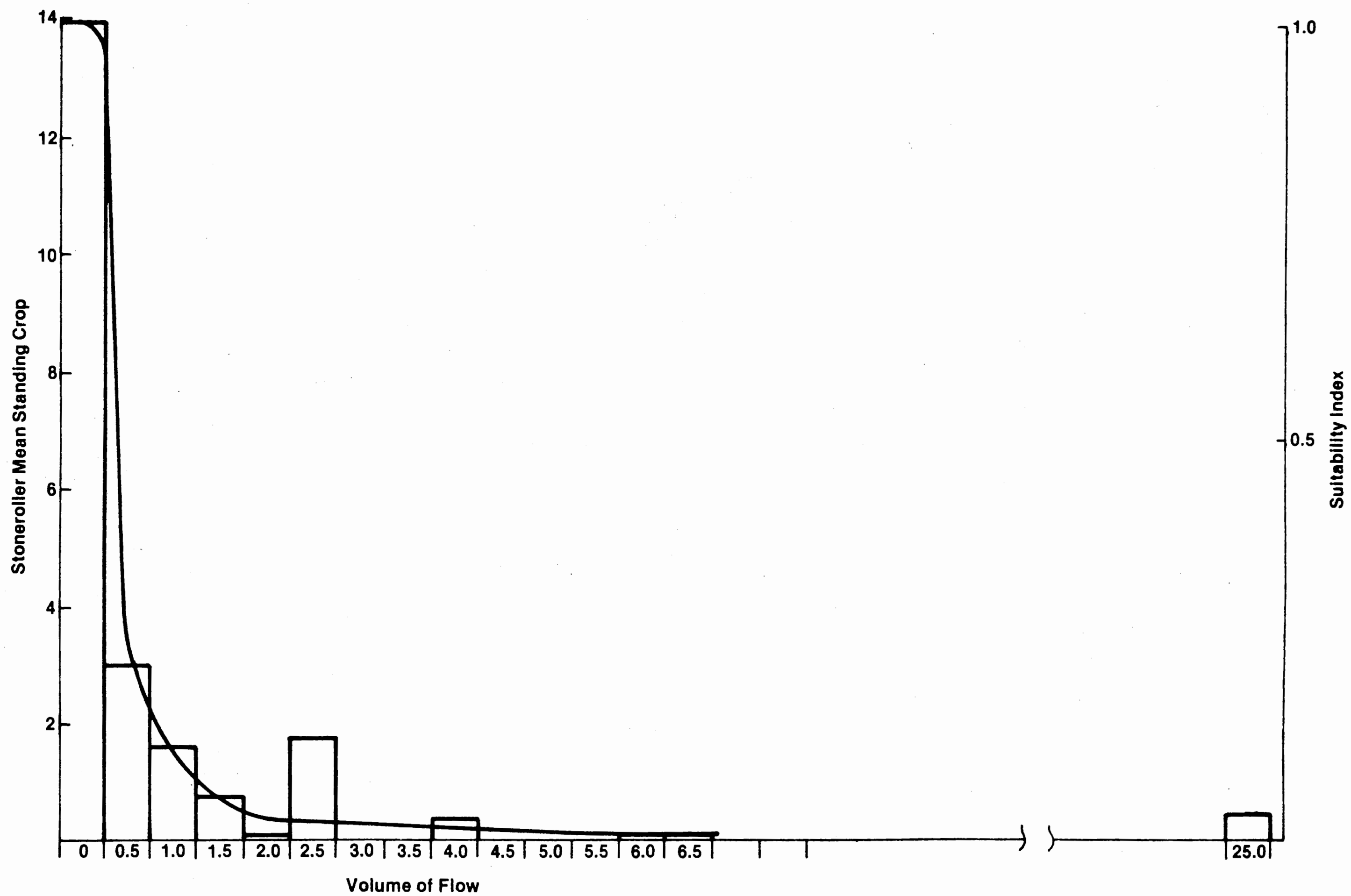


Figure 81. Relationship between central stoneroller mean standing crop (kg/ha) and volume of flow ($m^3/s$).

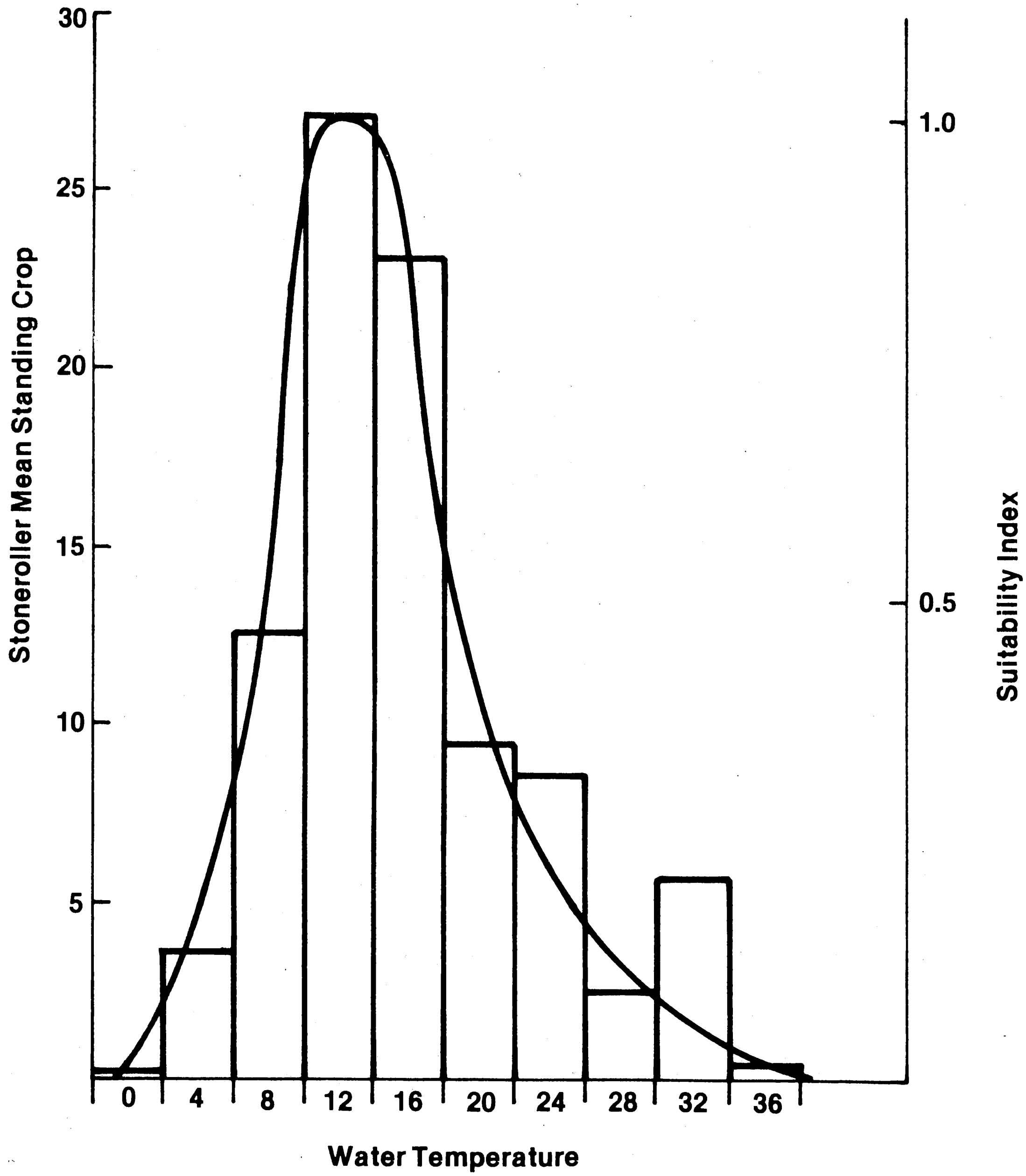


Figure 82. Relationship between central stoneroller mean standing crop (kg/ha) and water temperature (C).

APPENDIX E

CHANNEL CATFISH SUITABILITY CURVES (INTERVAL

RANGES, MEANS, AND N VALUES

GIVEN IN APPENDIX I)

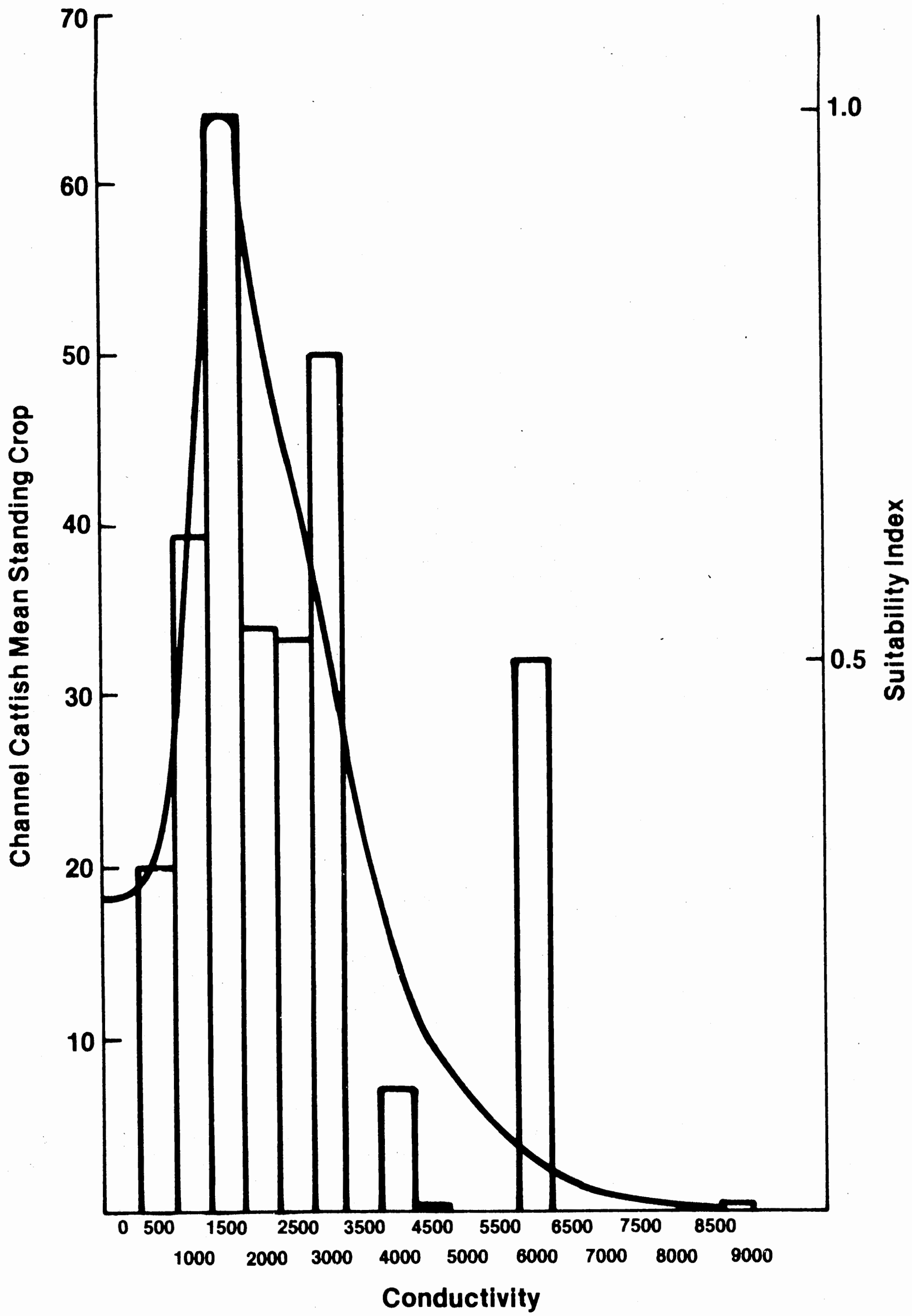


Figure 83. Relationship between channel catfish mean standing crop (kg/ha) and conductivity (μmhos/cm).

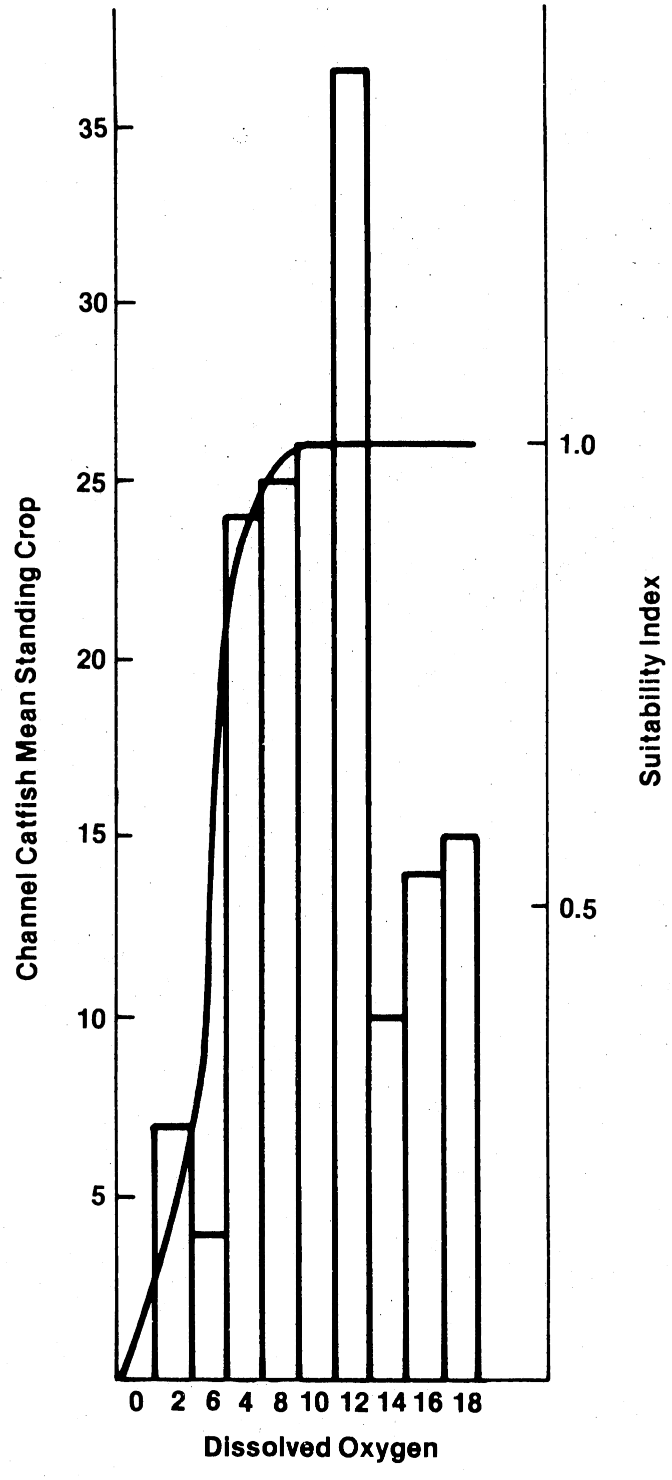


Figure 84. Relationship between channel catfish mean standing crop (kg/ha) and dissolved oxygen (mg/l).

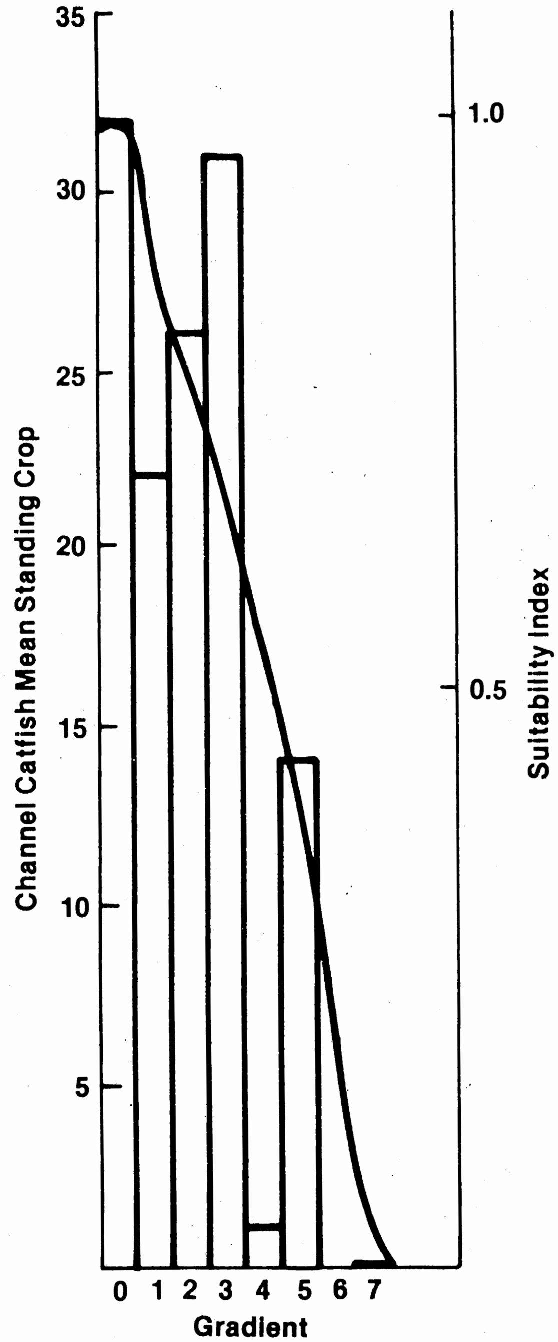


Figure 85. Relationship between channel catfish mean standing crop (kg/ha) and gradient (m/km).

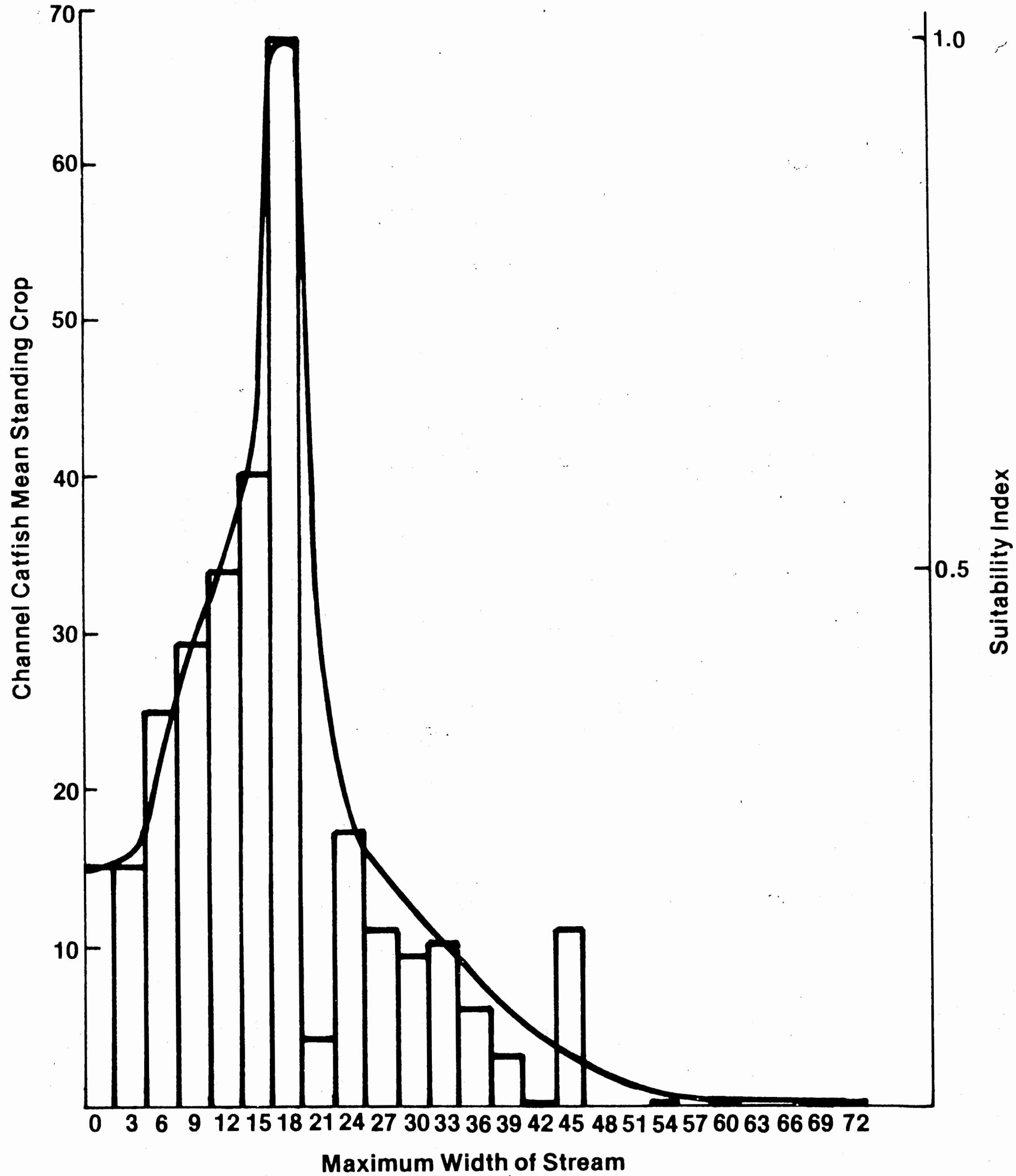


Figure 86. Relationship between channel catfish mean standing crop (kg/ha) and maximum stream width (m).

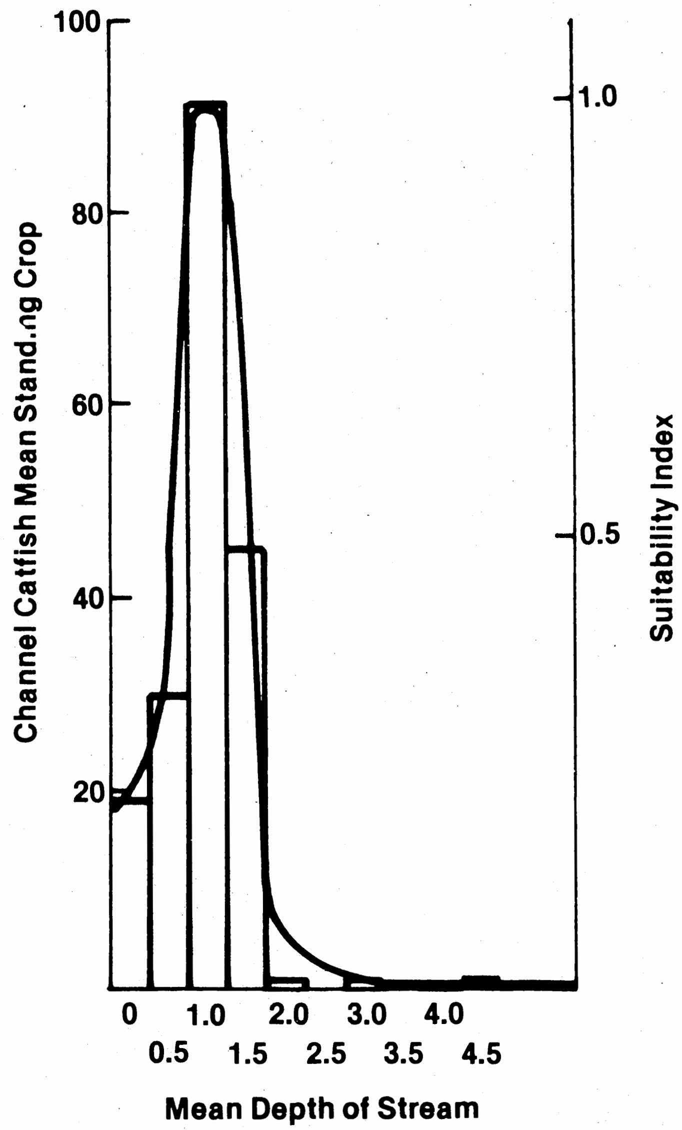


Figure 87. Relationship between channel catfish mean standing crop (kg/ha) and mean stream depth (m).

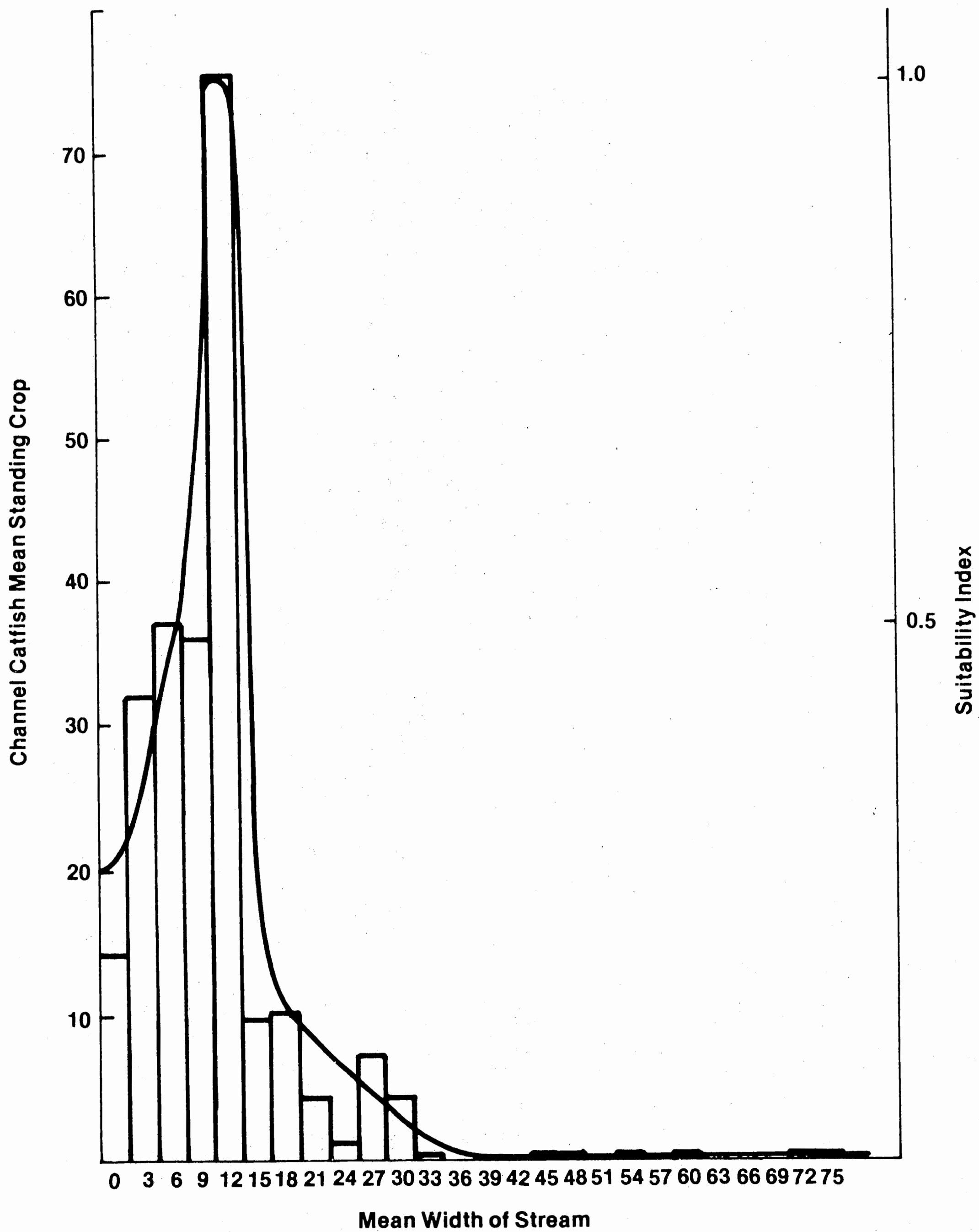


Figure 88. Relationship between channel catfish mean standing crop (kg/ha) and mean stream width (m).

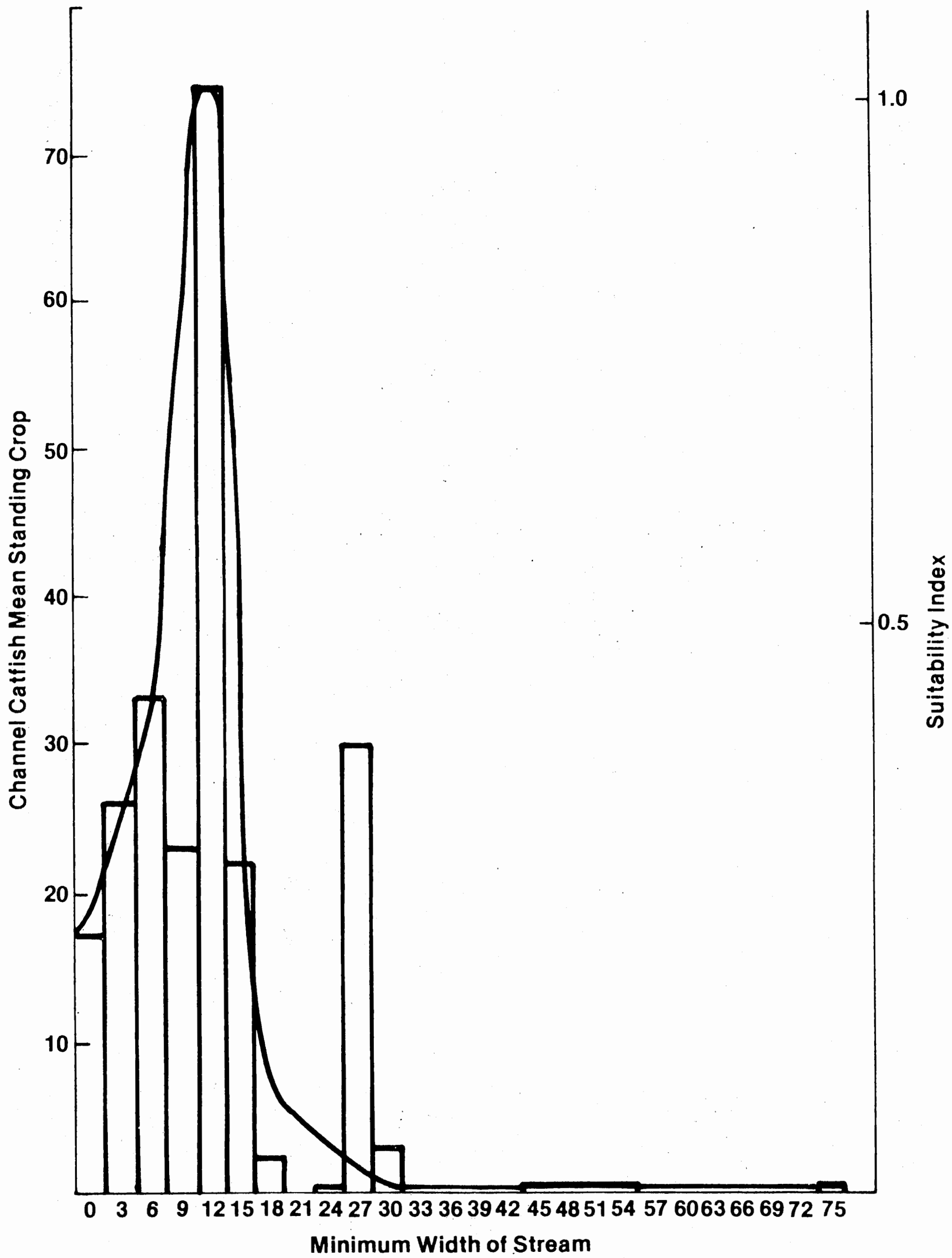


Figure 89. Relationship between channel catfish mean standing crop (kg/ha) and minimum stream width (m).

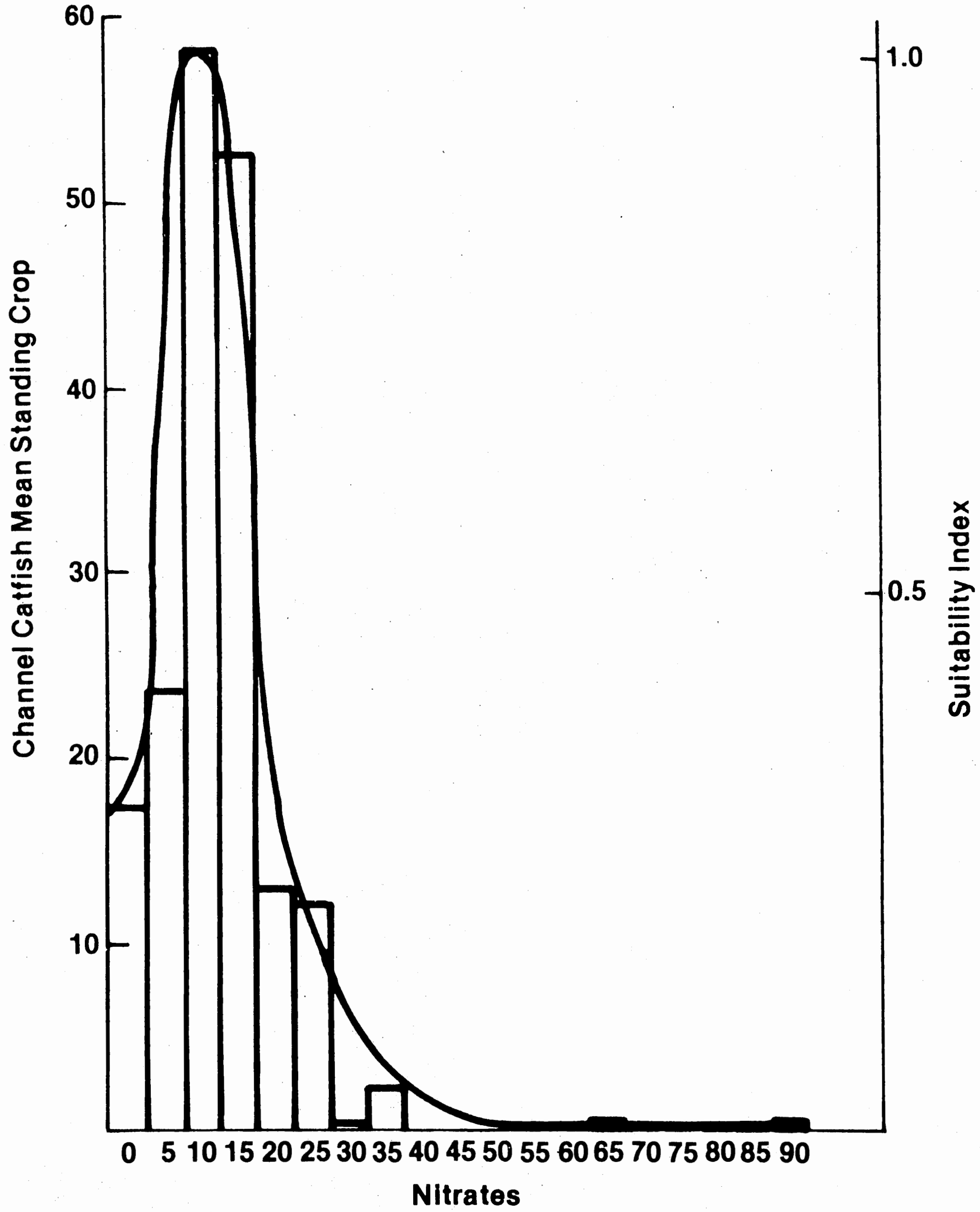


Figure 90. Relationship between channel catfish mean standing crop (kg/ha) and nitrates (mg/l).

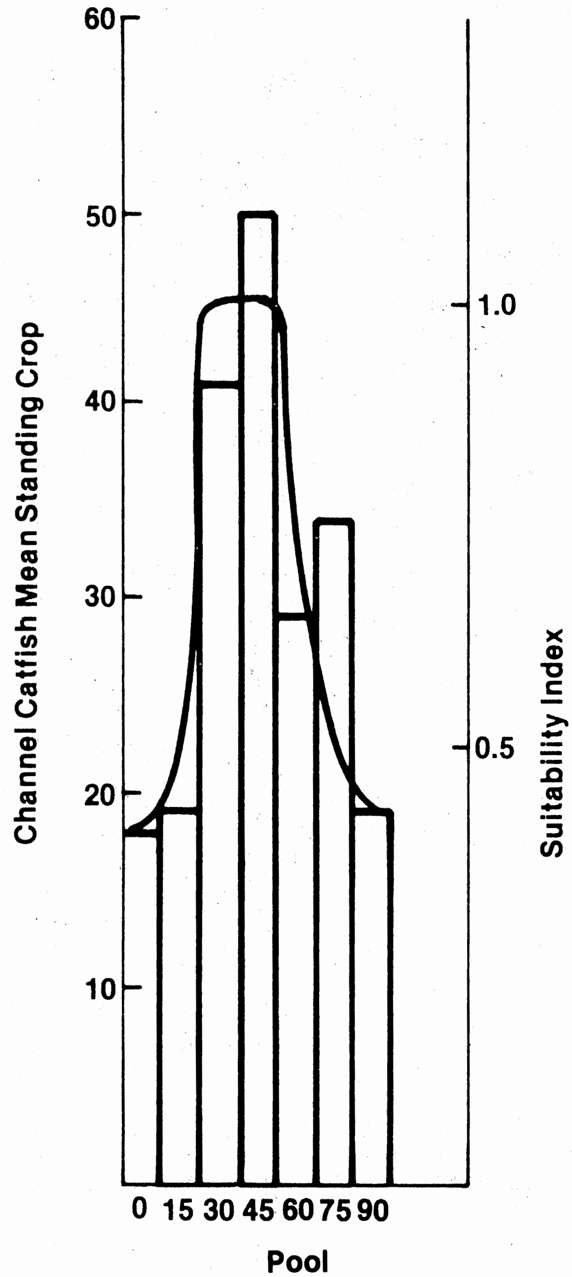


Figure 91. Relationship between channel catfish mean standing crop (kg/ha) and percent pool.

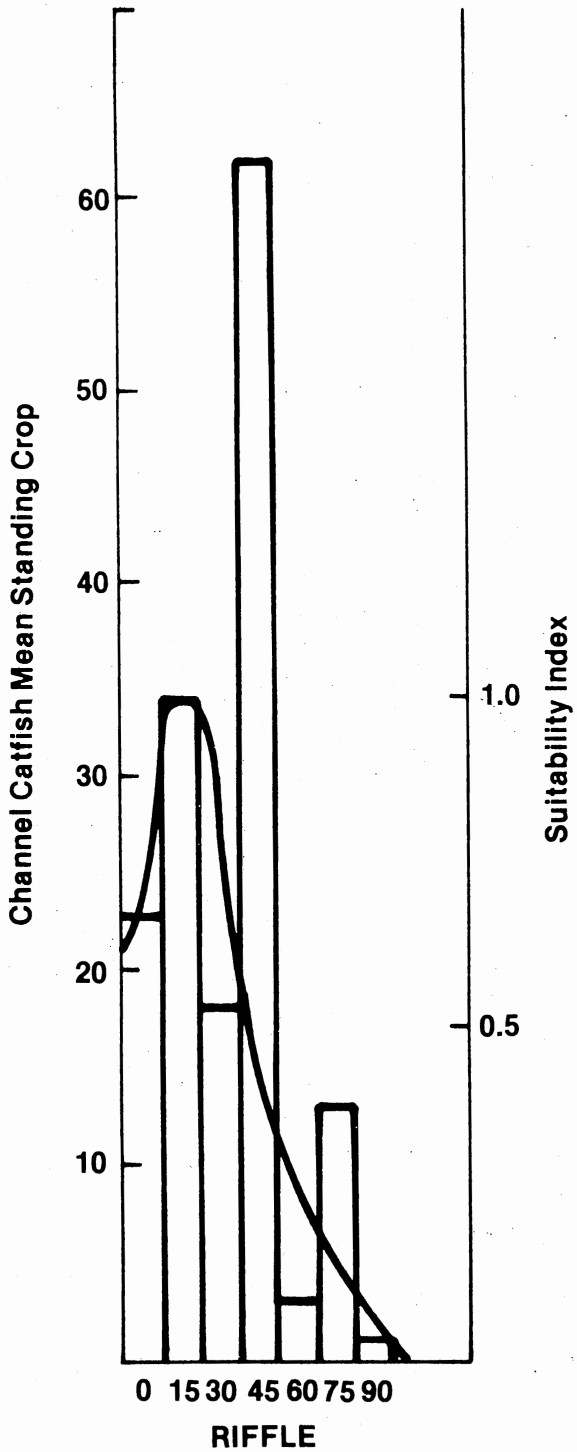


Figure 92. Relationship between channel catfish mean standing crop (kg/ha) and percent riffle.

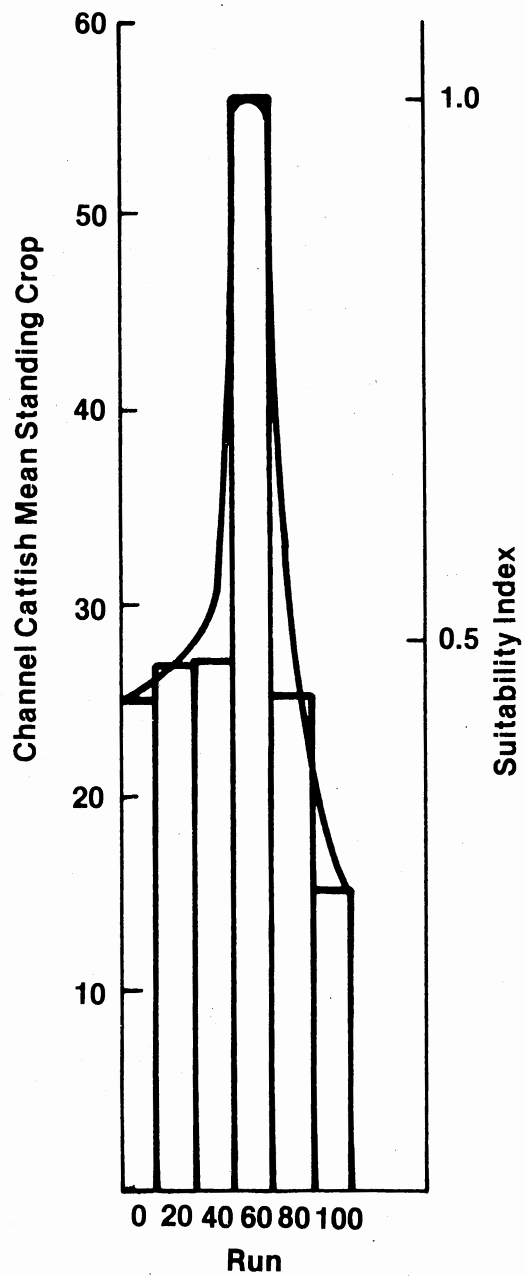


Figure 93. Relationship between channel catfish mean standing crop (kg/ha) and percent run.

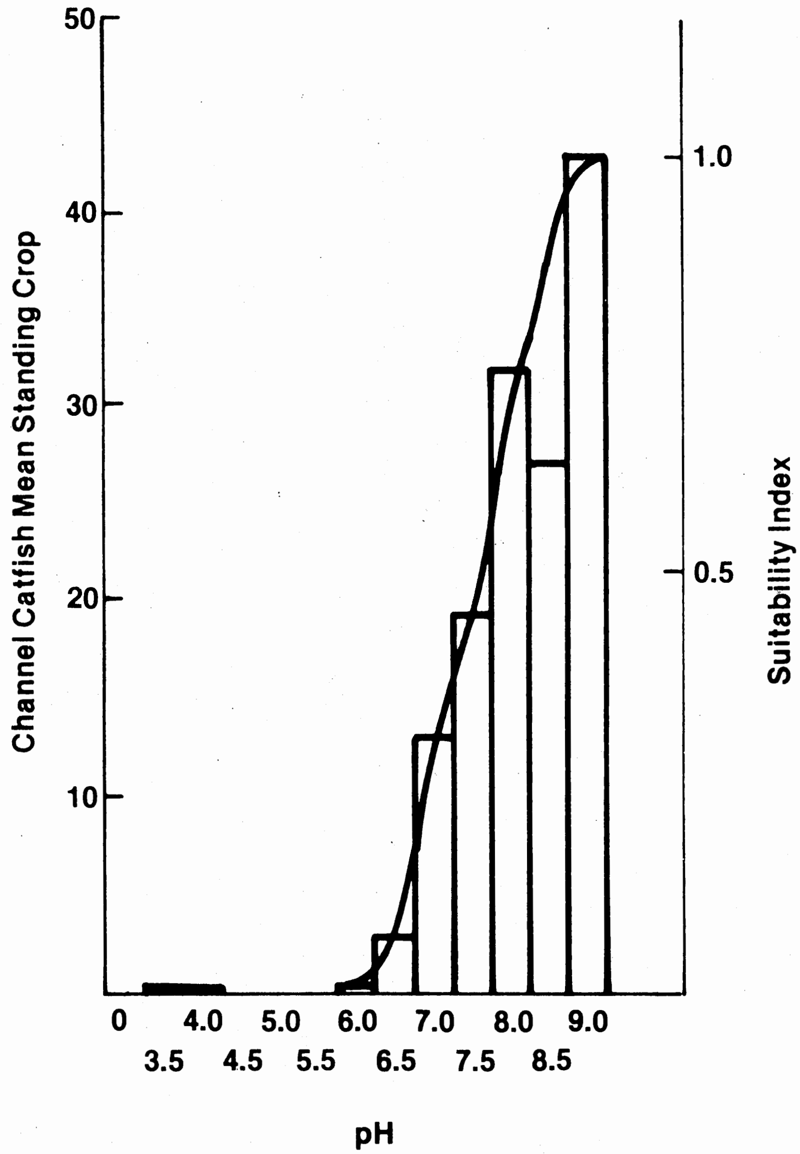


Figure 94. Relationship between channel catfish mean standing crop (kg/ha) and pH.

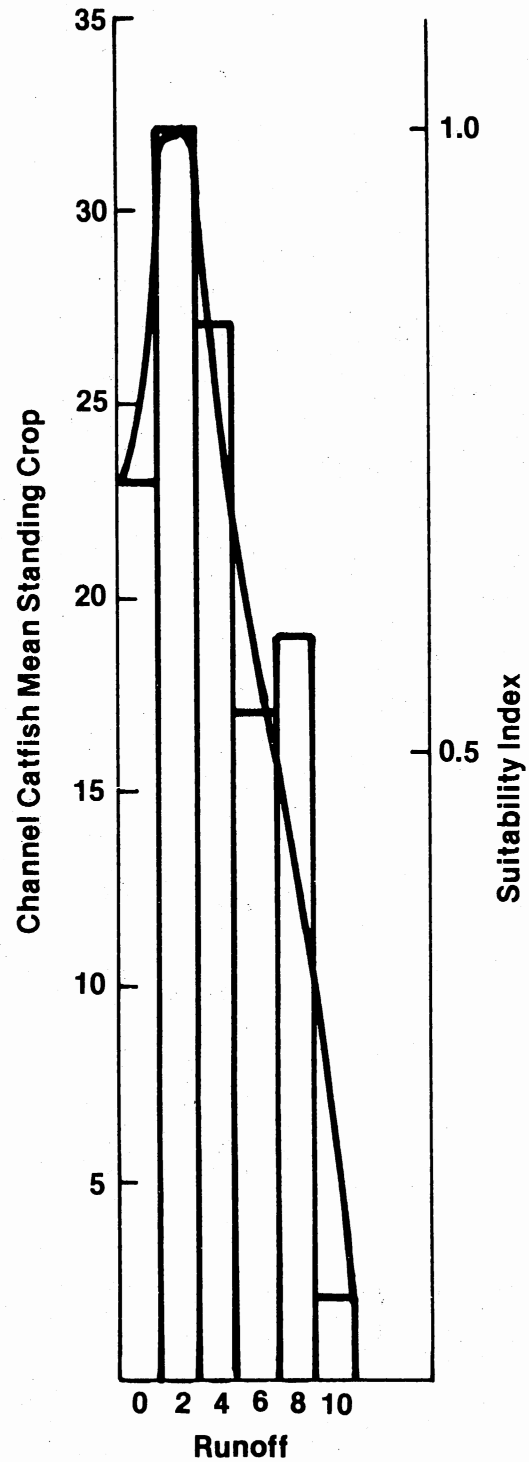


Figure 95. Relationship between channel catfish mean standing crop (kg/ha) and runoff (in/yr).

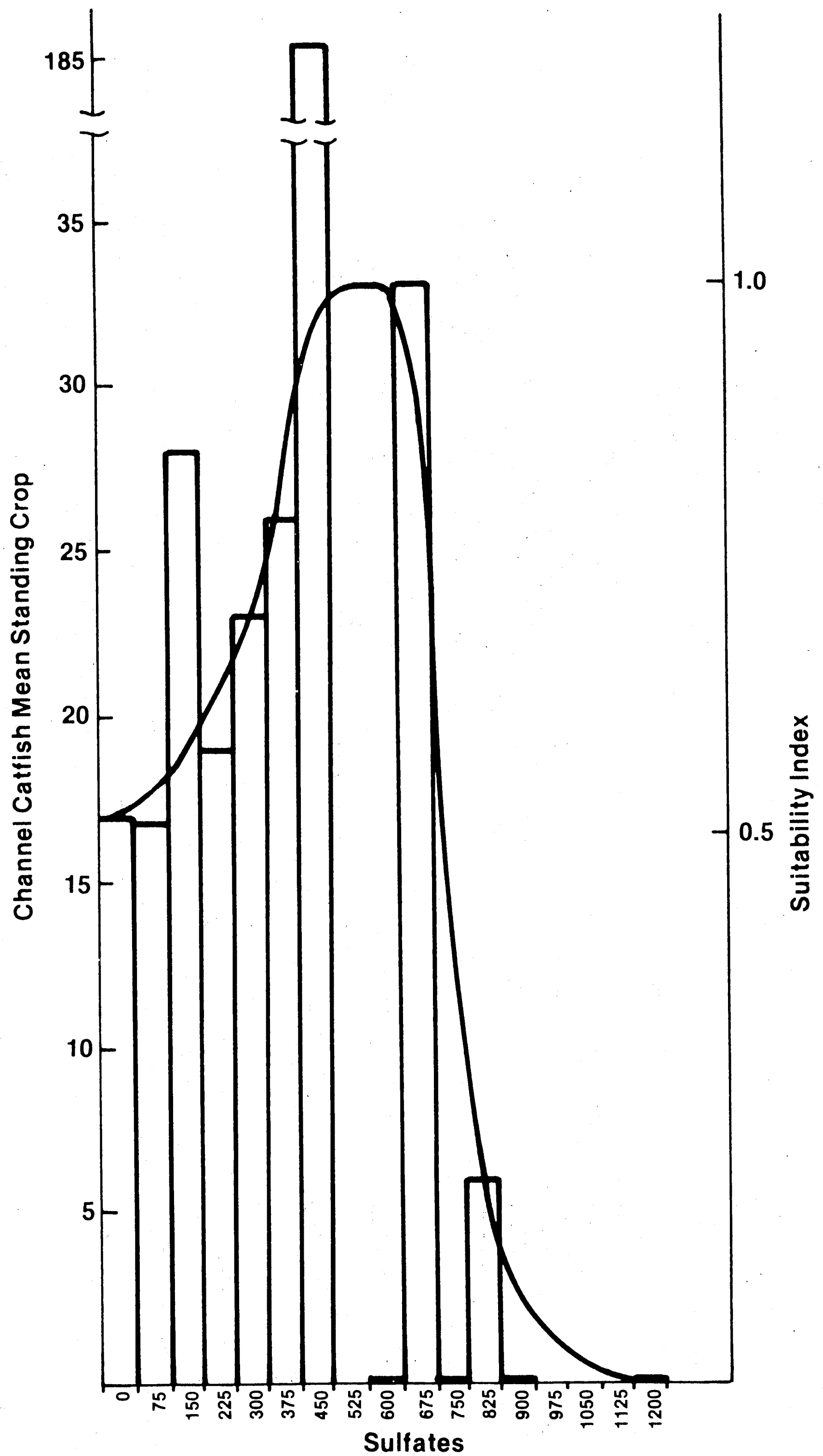


Figure 96. Relationship between channel catfish mean standing crop (kg/ha) and sulfates (mg/l).

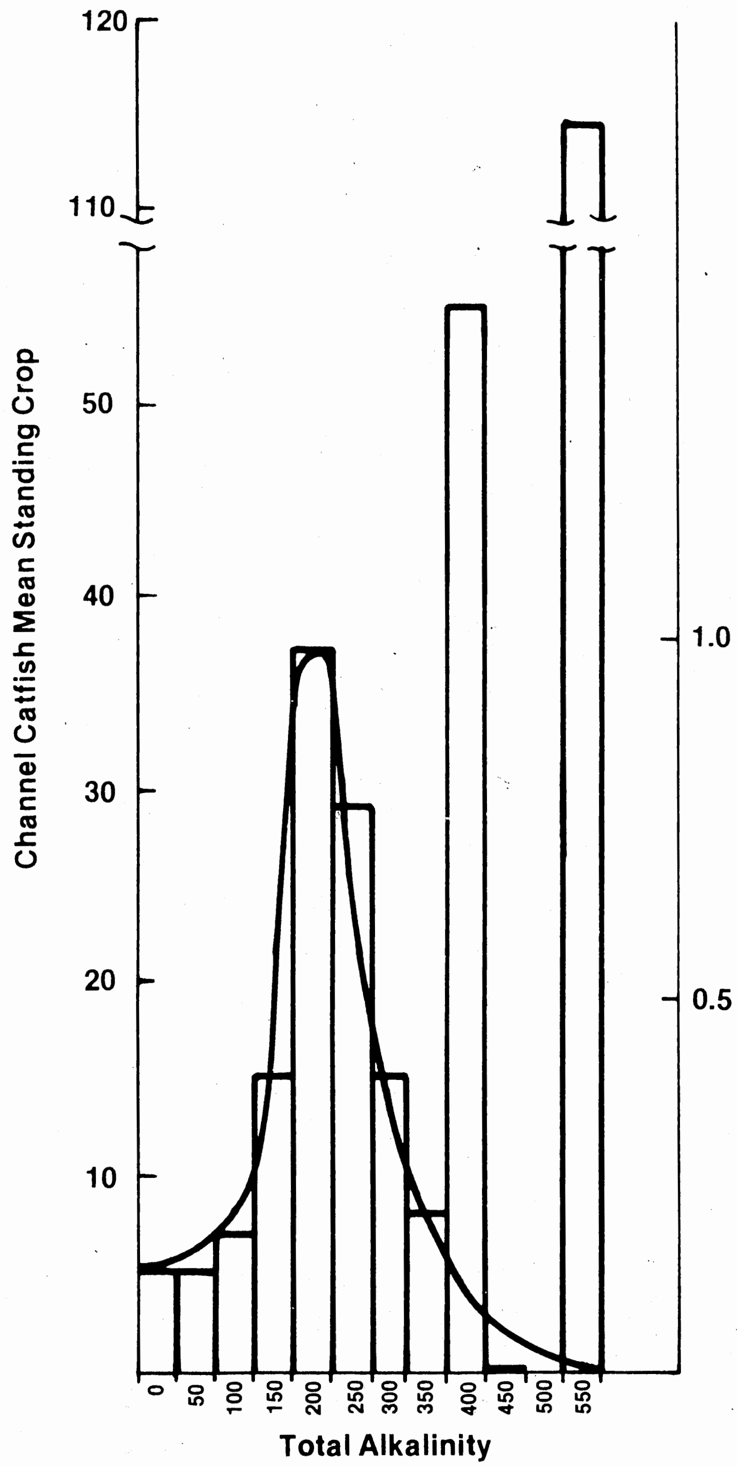


Figure 97. Relationship between channel catfish mean standing crop (kg/ha) and total alkalinity (mg/l).

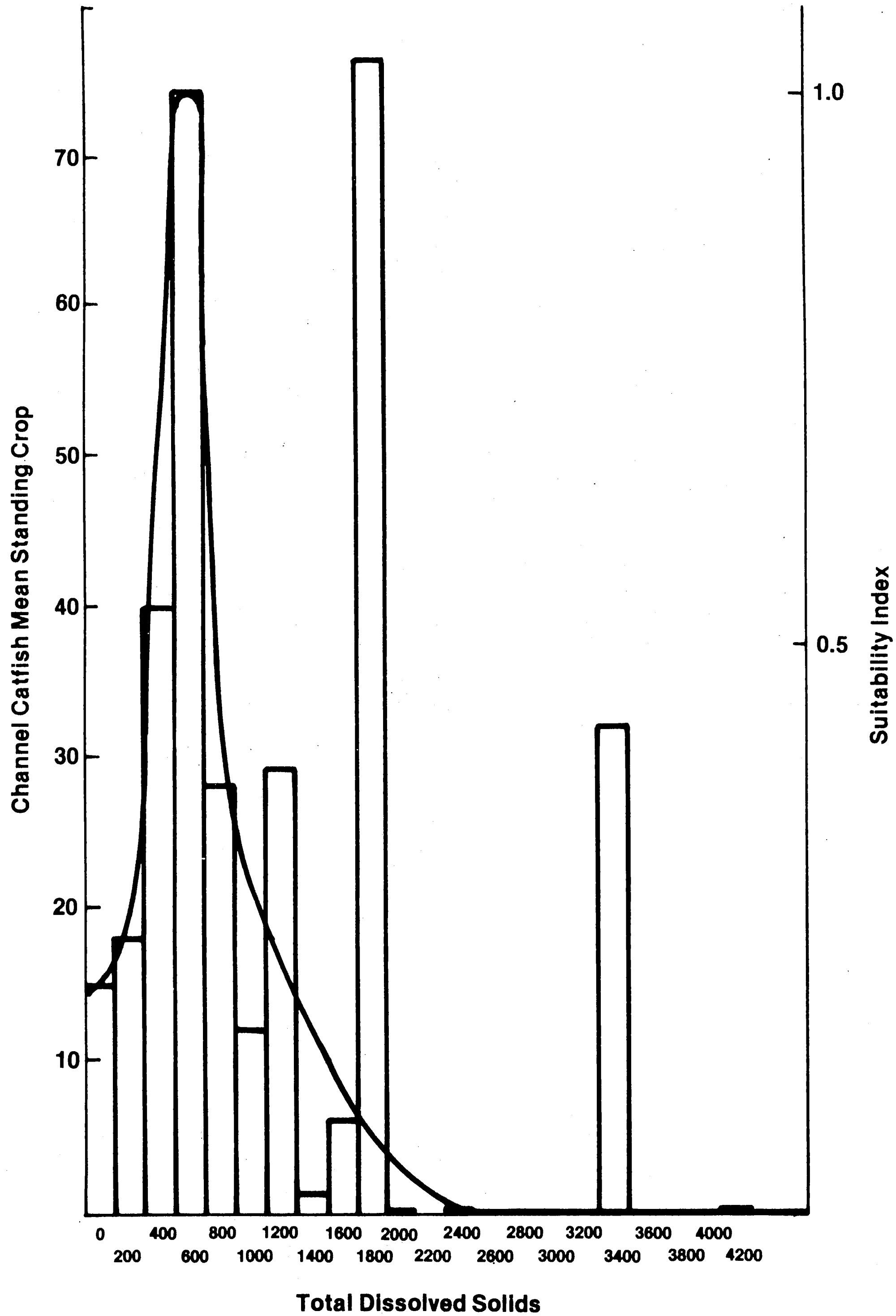


Figure 98. Relationship between channel catfish mean standing crop (kg/ha) and total dissolved solids (mg/l).

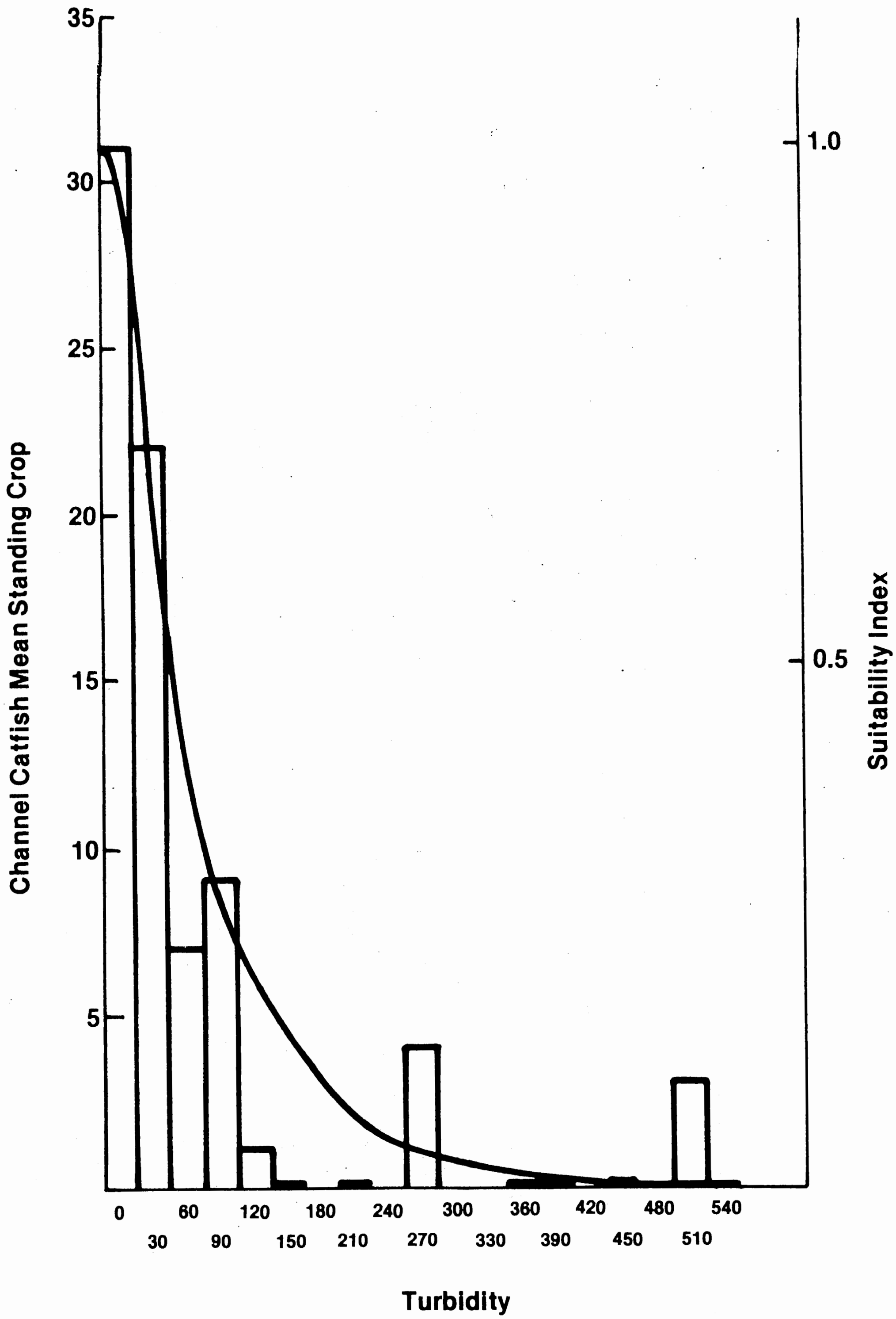


Figure 99. Relationship between channel catfish mean standing crop (kg/ha) and turbidity (JTU's).

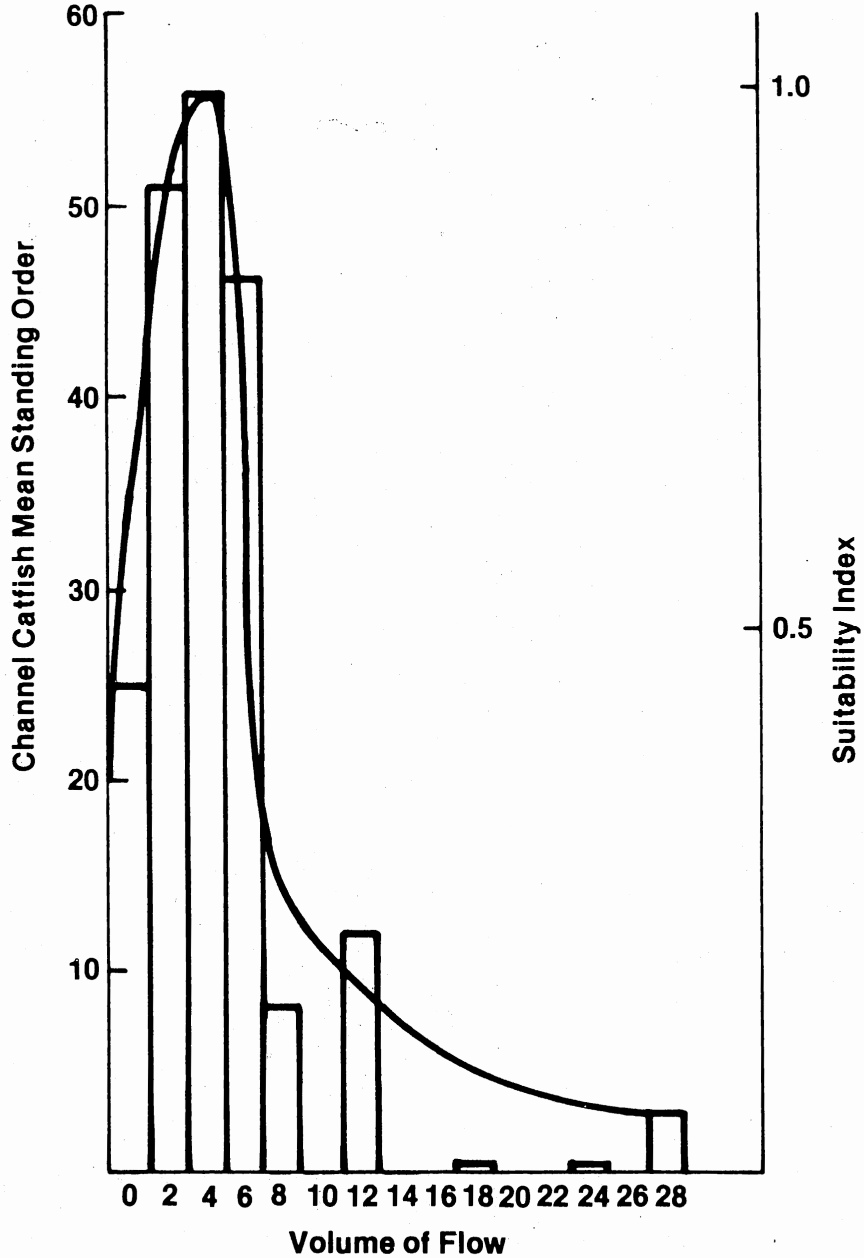


Figure 100. Relationahip between channel catfish mean standing crop (kg/ha) and volume of flow ($m^3/s$).

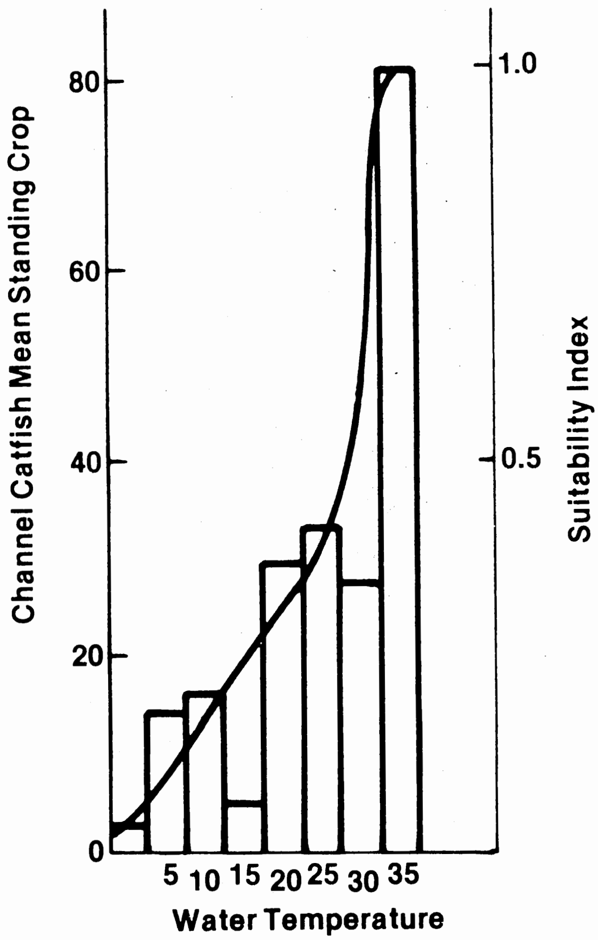


Figure 101. Relationship between channel catfish mean standing crop (kg/ha) and water temperature (C).

# APPENDIX F

## LARGEMOUTH BASS SUITABILITY CURVES (INTERVAL RANGES, MEANS, AND N VALUES GIVEN IN APPENDIX I)

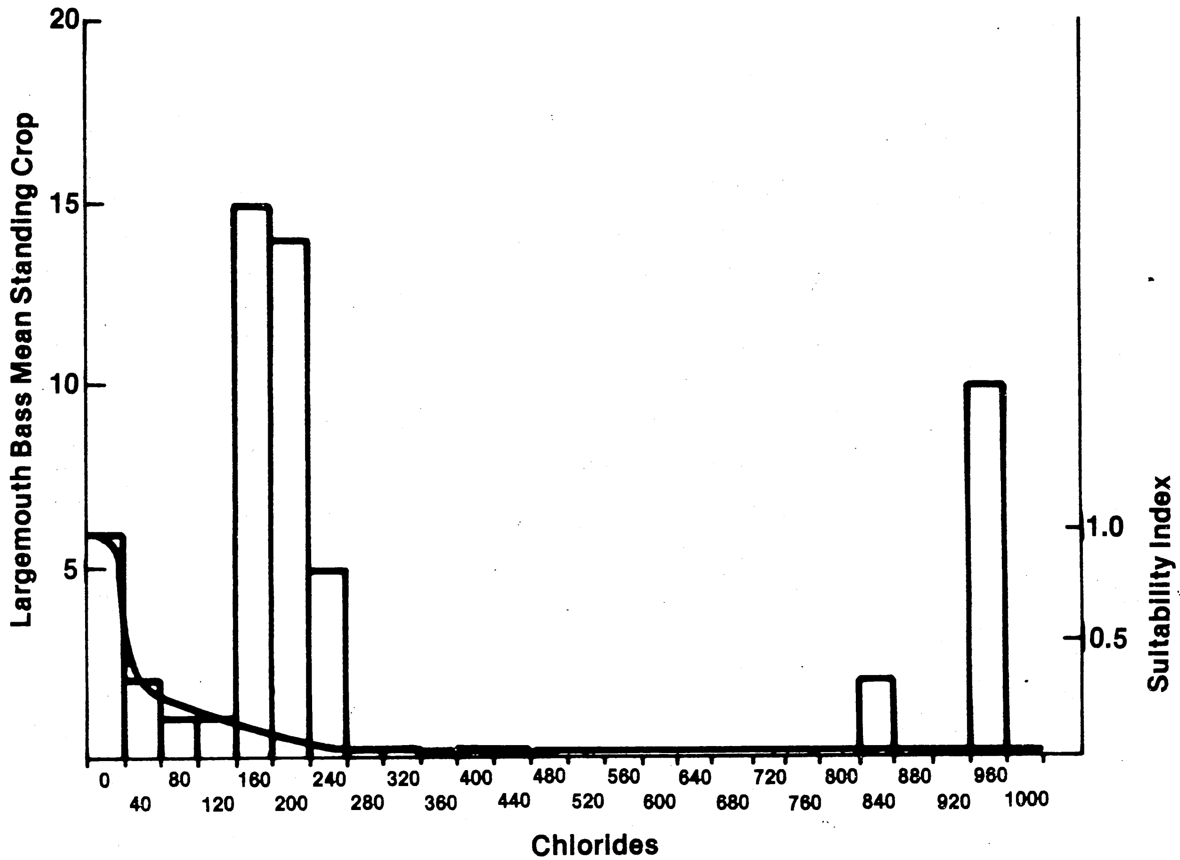


Figure 102. Relationship between largemouth bass mean standing crop (kg/ha) and chlorides (mg/l).

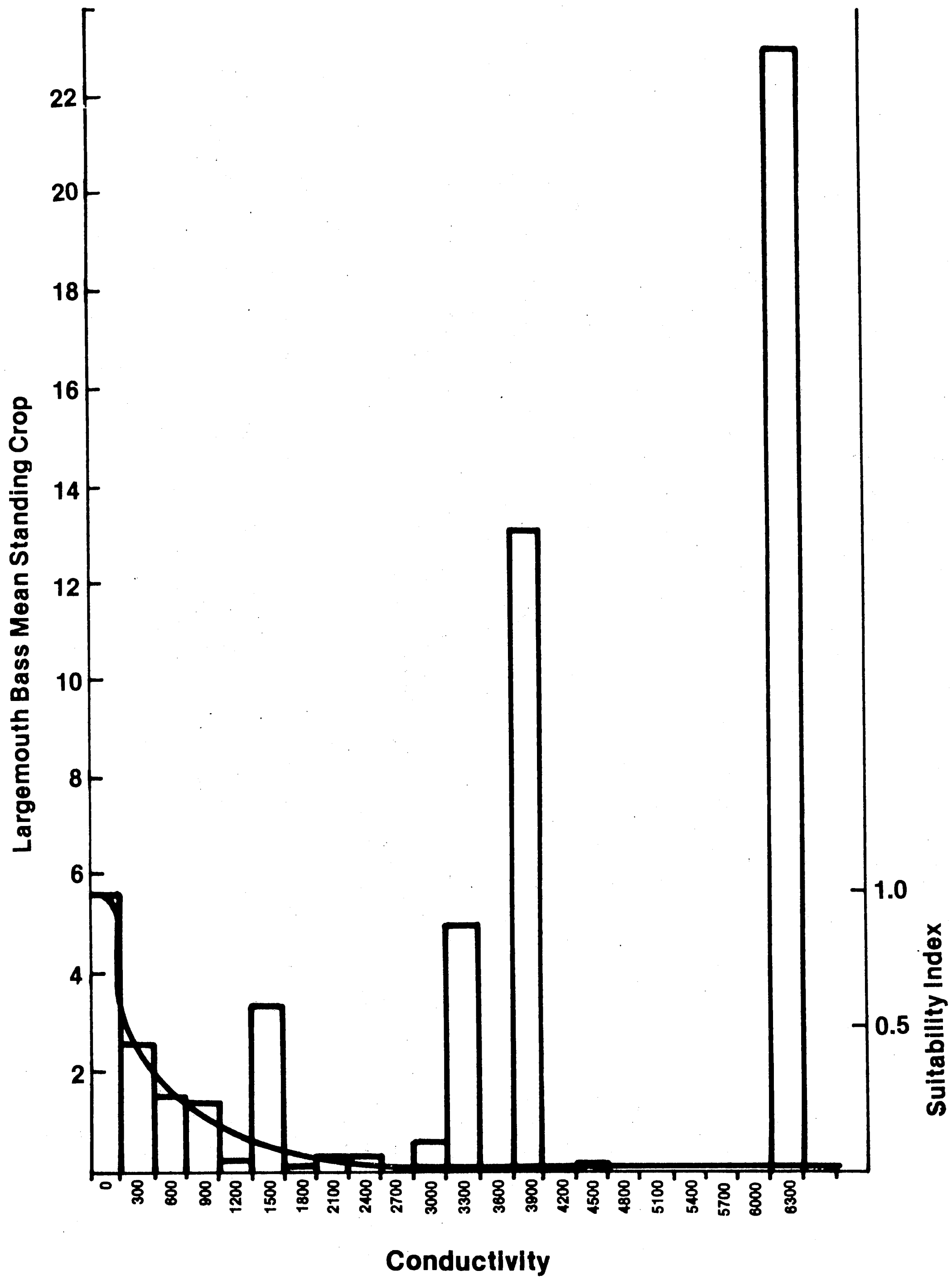


Figure 103. Relationship between largemouth bass mean standing crop (kg/ha) and conductivity (μmhos/cm).

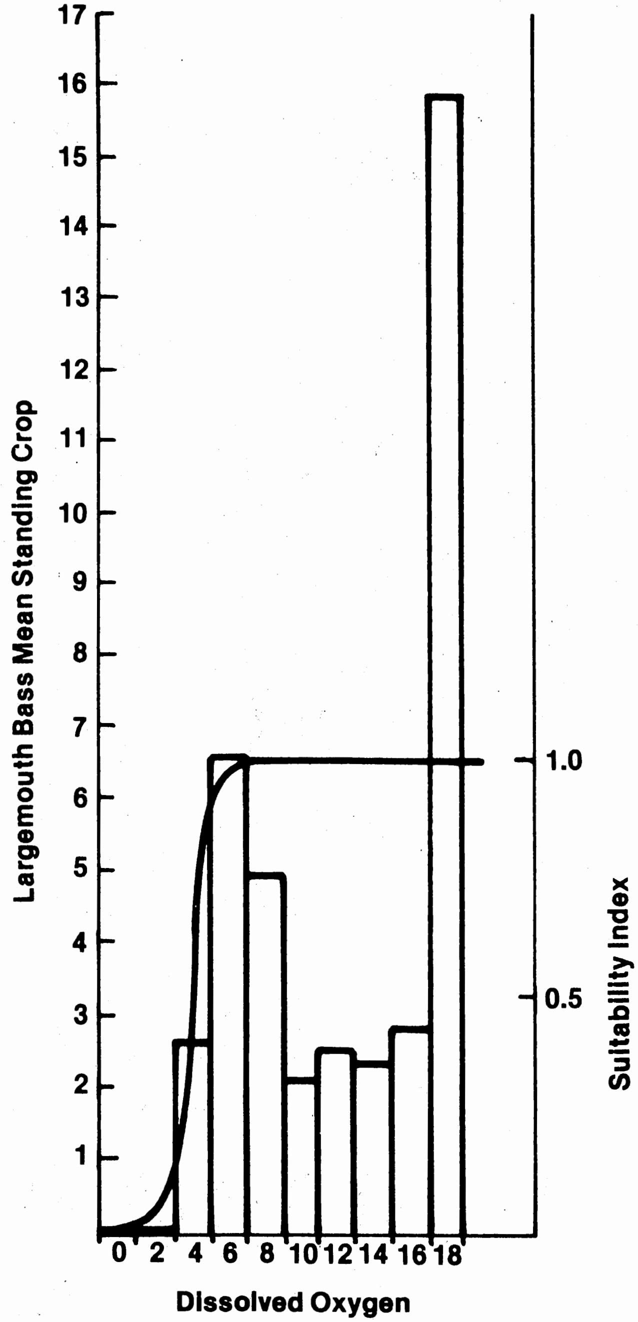


Figure 104. Relationship between large-mouth bass mean standing crop (kg/ha) and dissolved oxygen (mg/l).

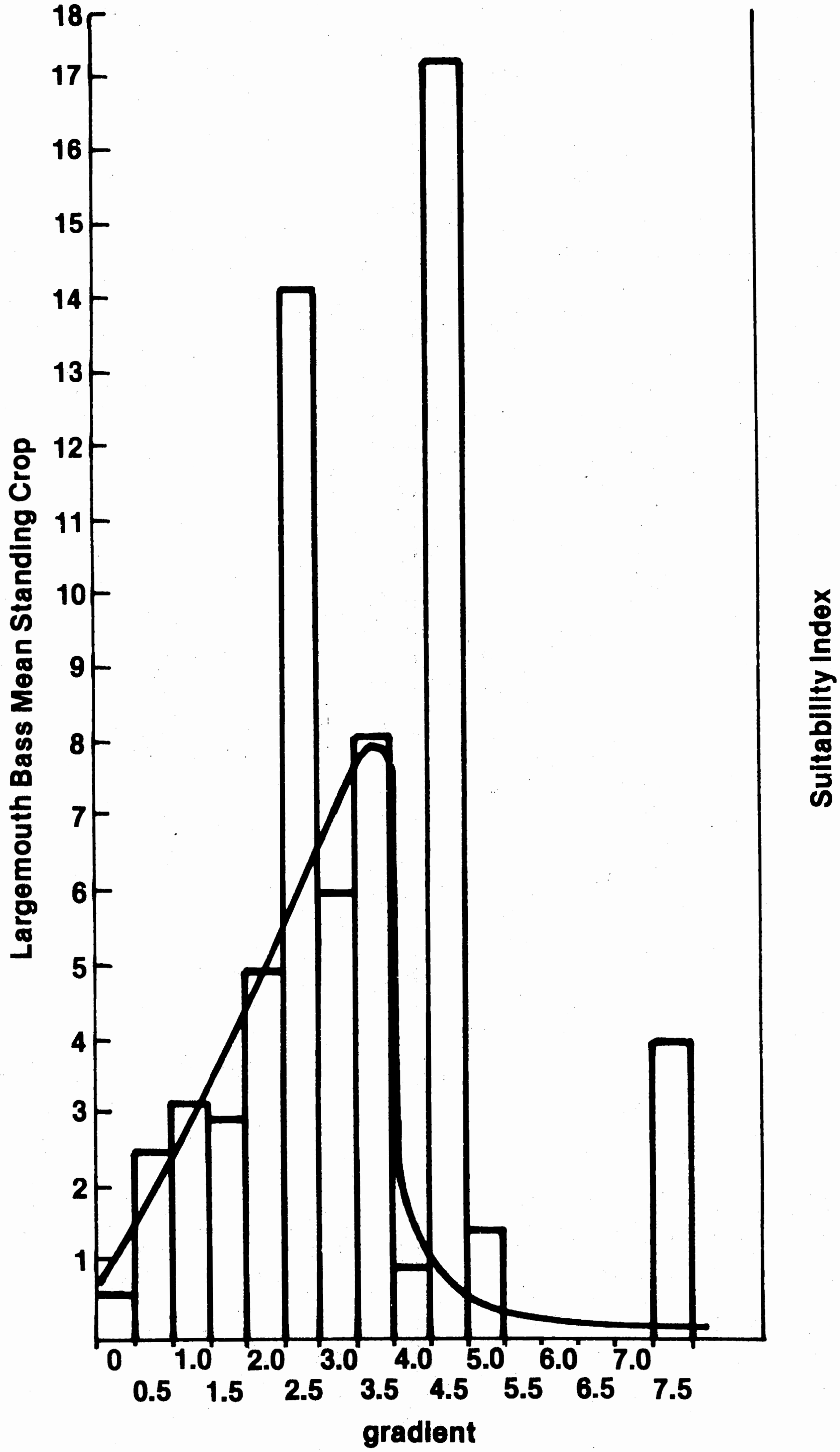


Figure 105. Relationship between largemouth bass mean standing crop (kg/ha) and gradient (m/km).

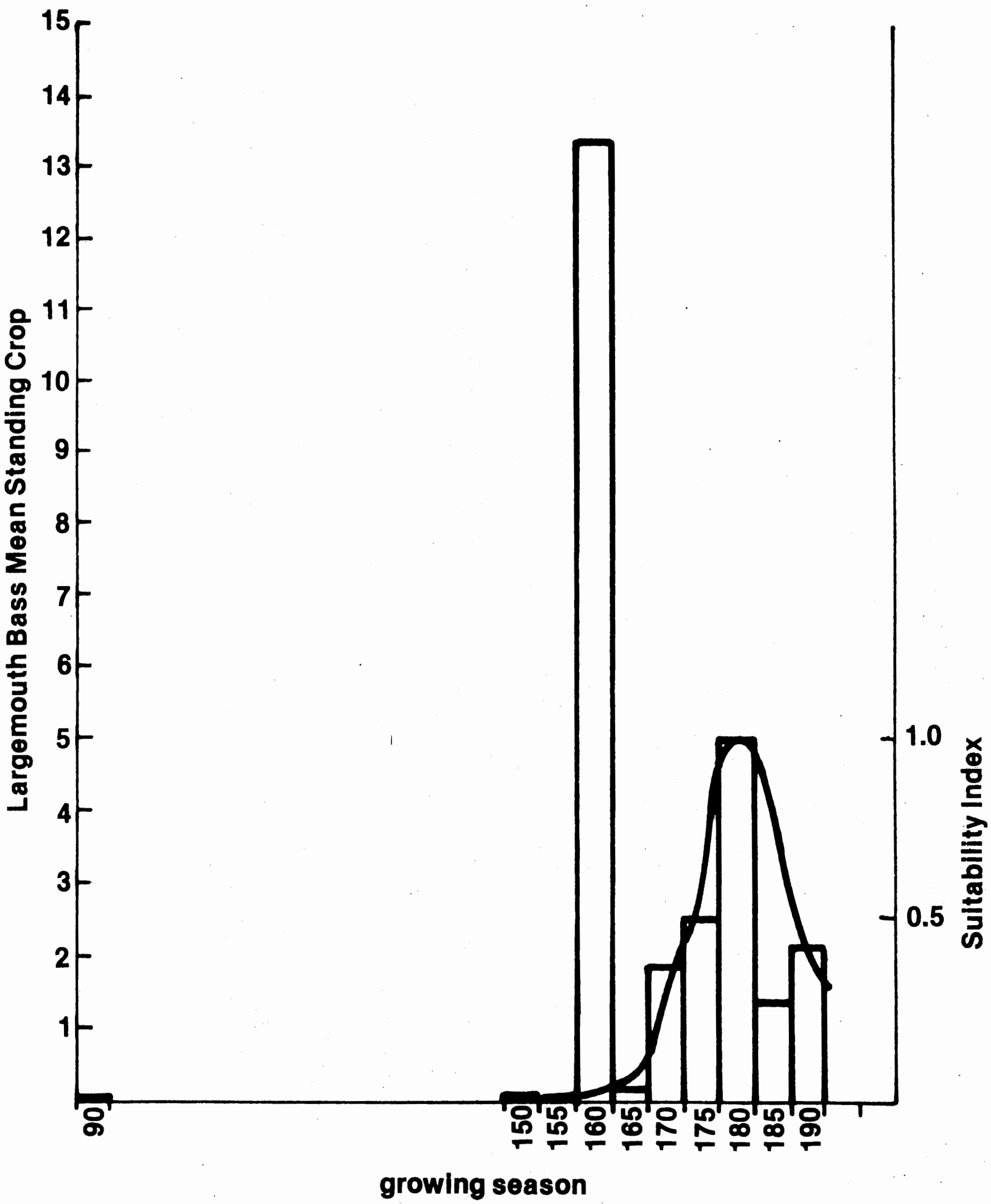


Figure 106. Relationship between largemouth bass mean standing crop (kg/ha) and growing season (frost-free days).

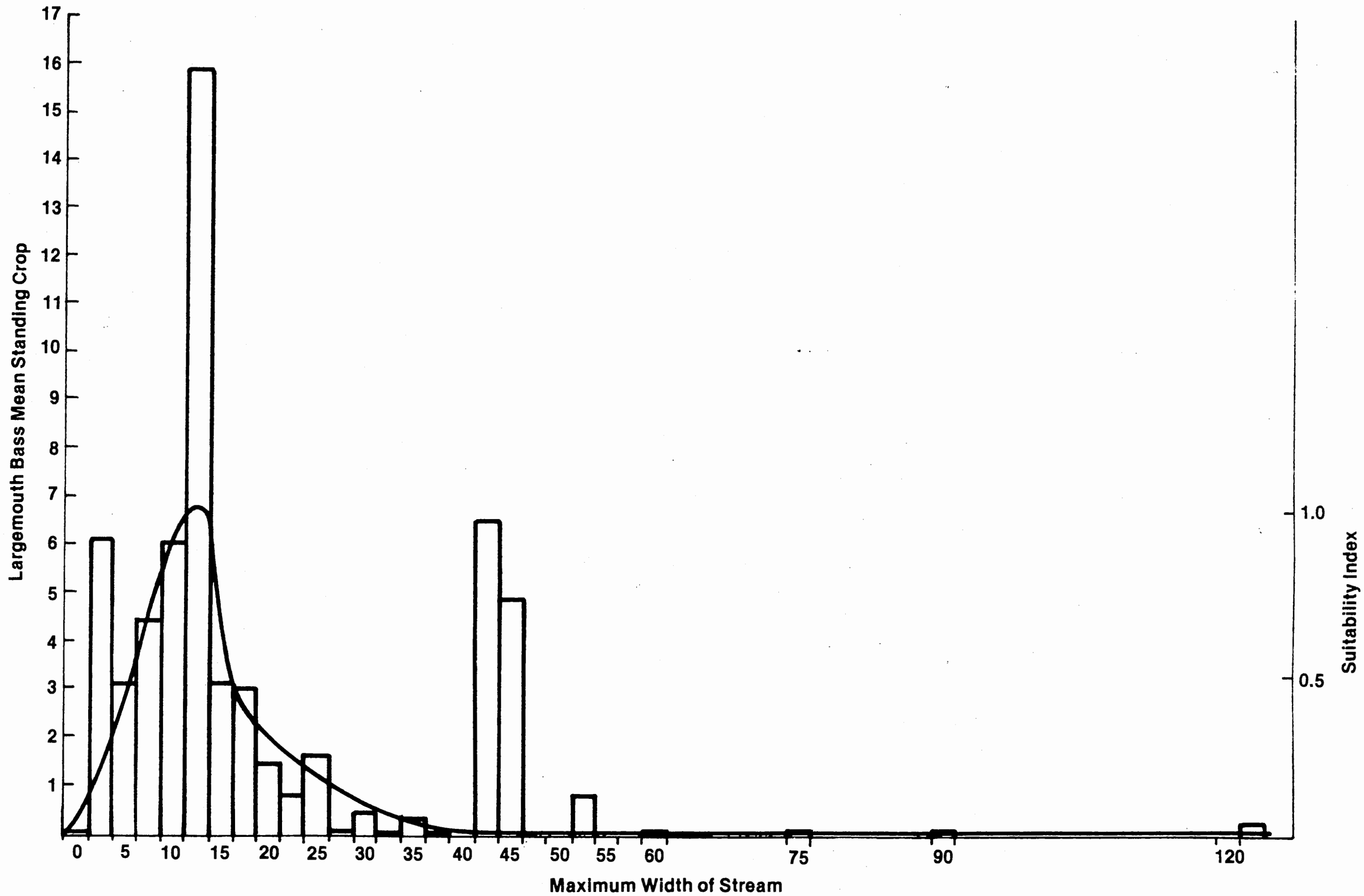


Figure 107. Relationship between largemouth bass mean standing crop (kg/ha) and maximum stream width (m).

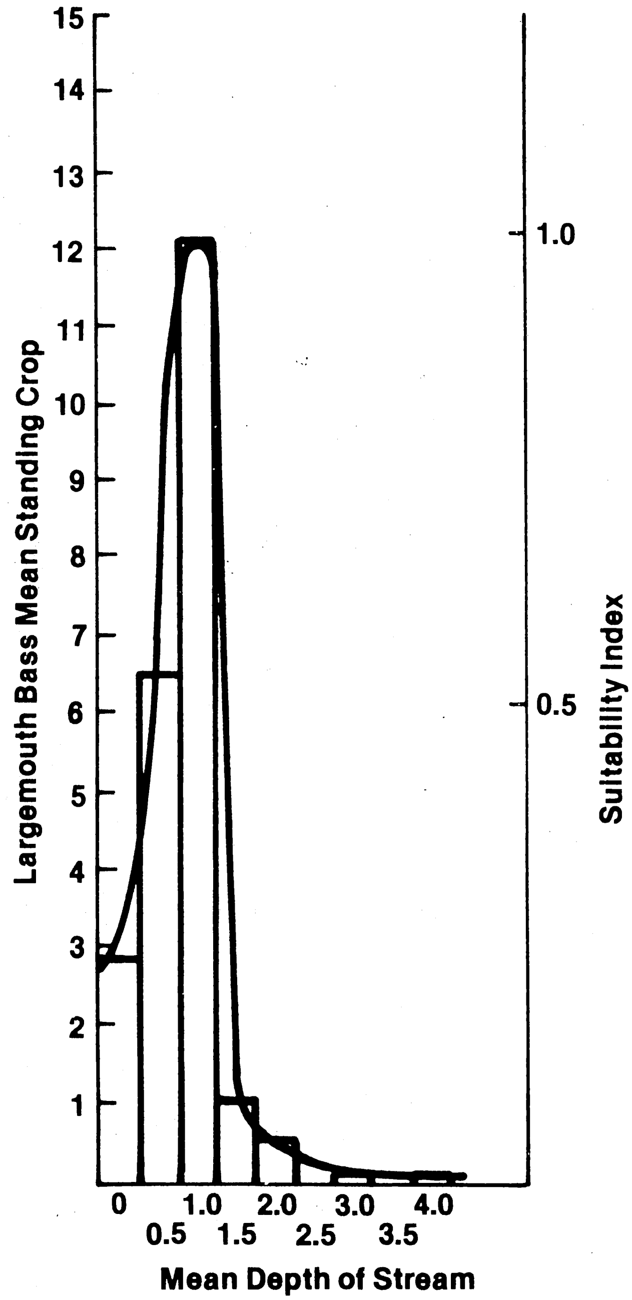


Figure 108. Relationship between largemouth bass mean standing crop (kg/ha) and mean stream depth (m).

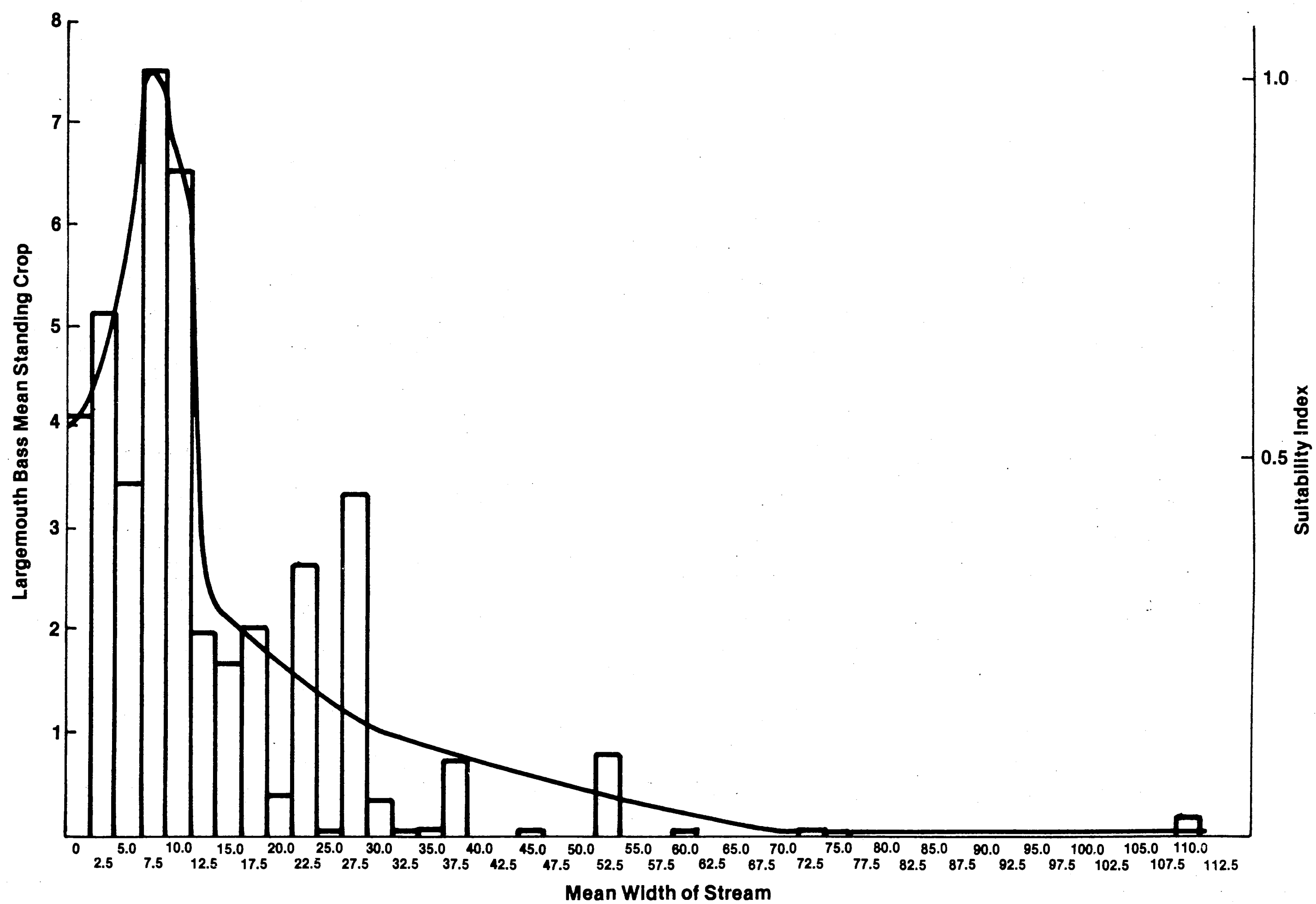


Figure 109. Relationship between largemouth bass mean standing crop (kg/ha) and mean stream width (m).

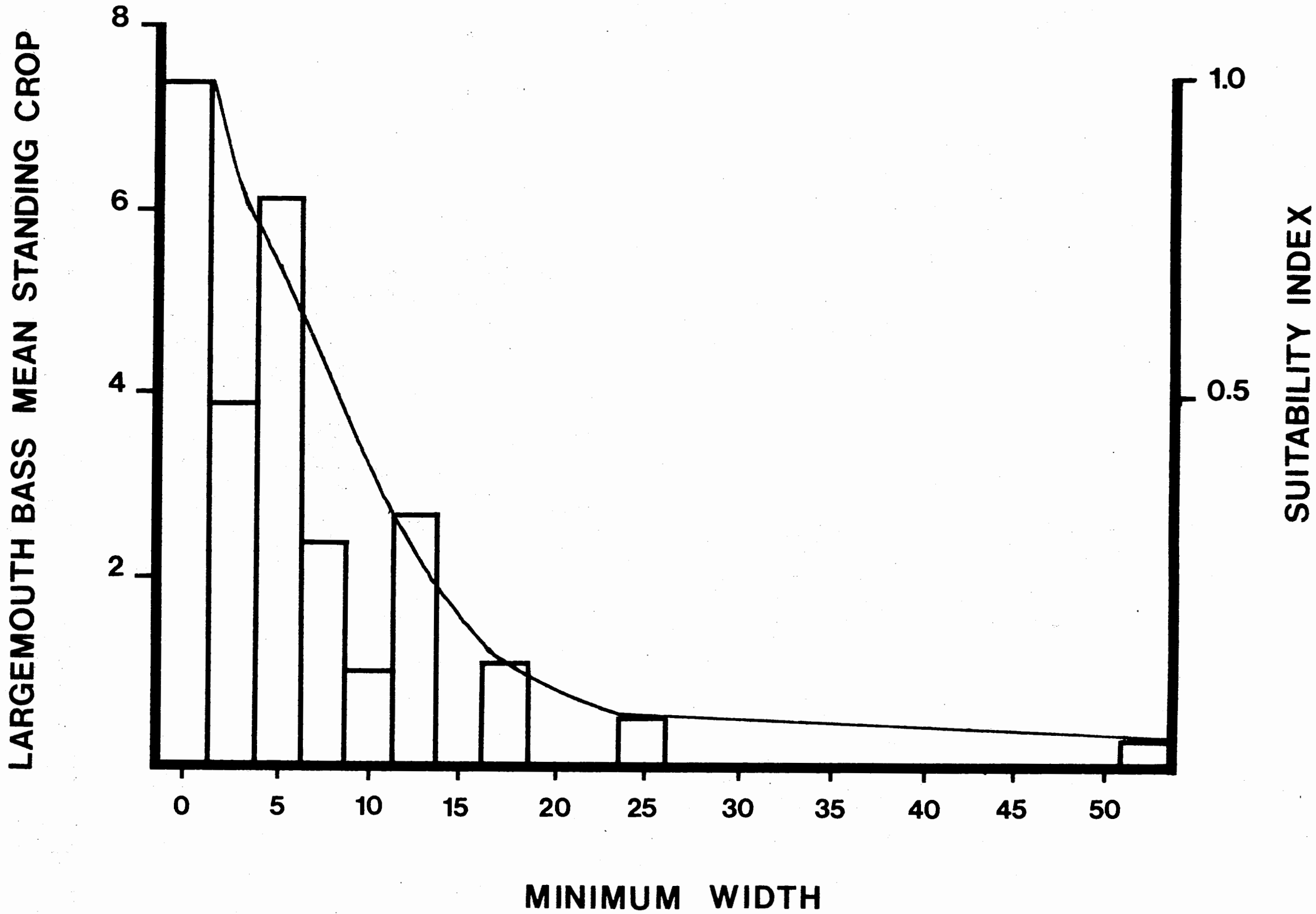


Figure 110. Relationship between largemouth bass mean standing crop (kg/ha) and minimum stream width (m).

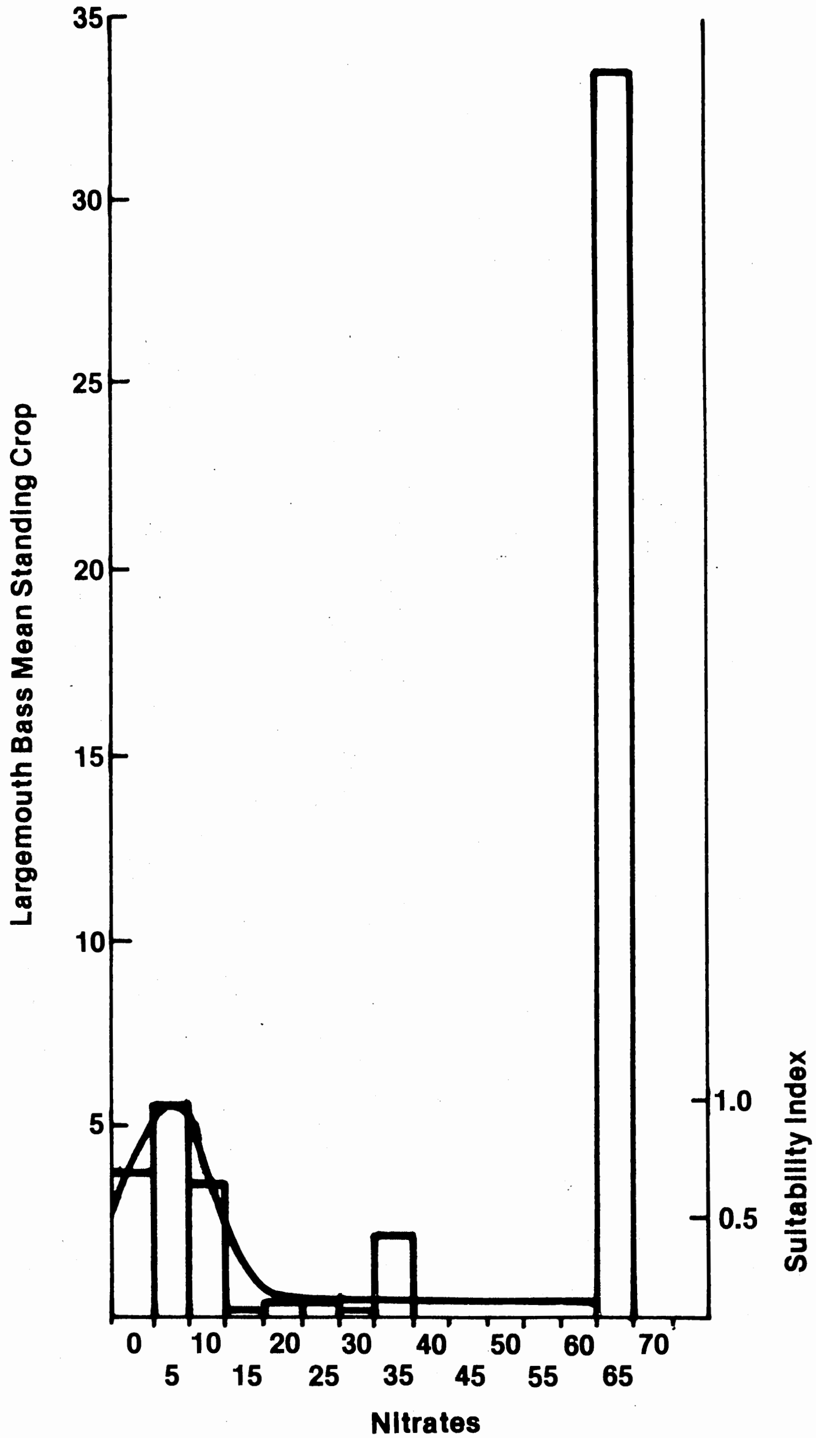


Figure 111. Relationship between largemouth bass mean standing crop (kg/ha) and nitrates (mg/l).

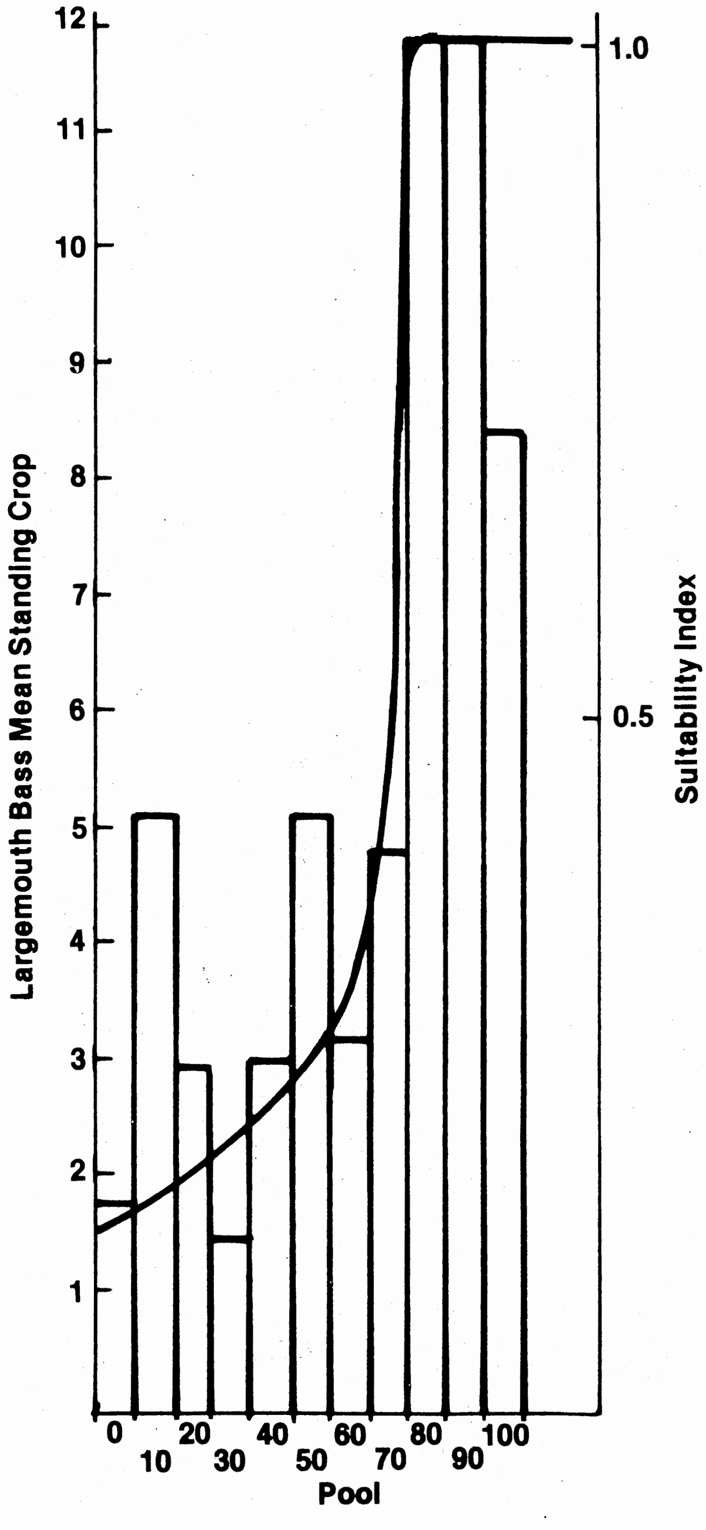


Figure 112. Relationship between large-mouth bass mean standing crop (kg/ha) and percent pool.

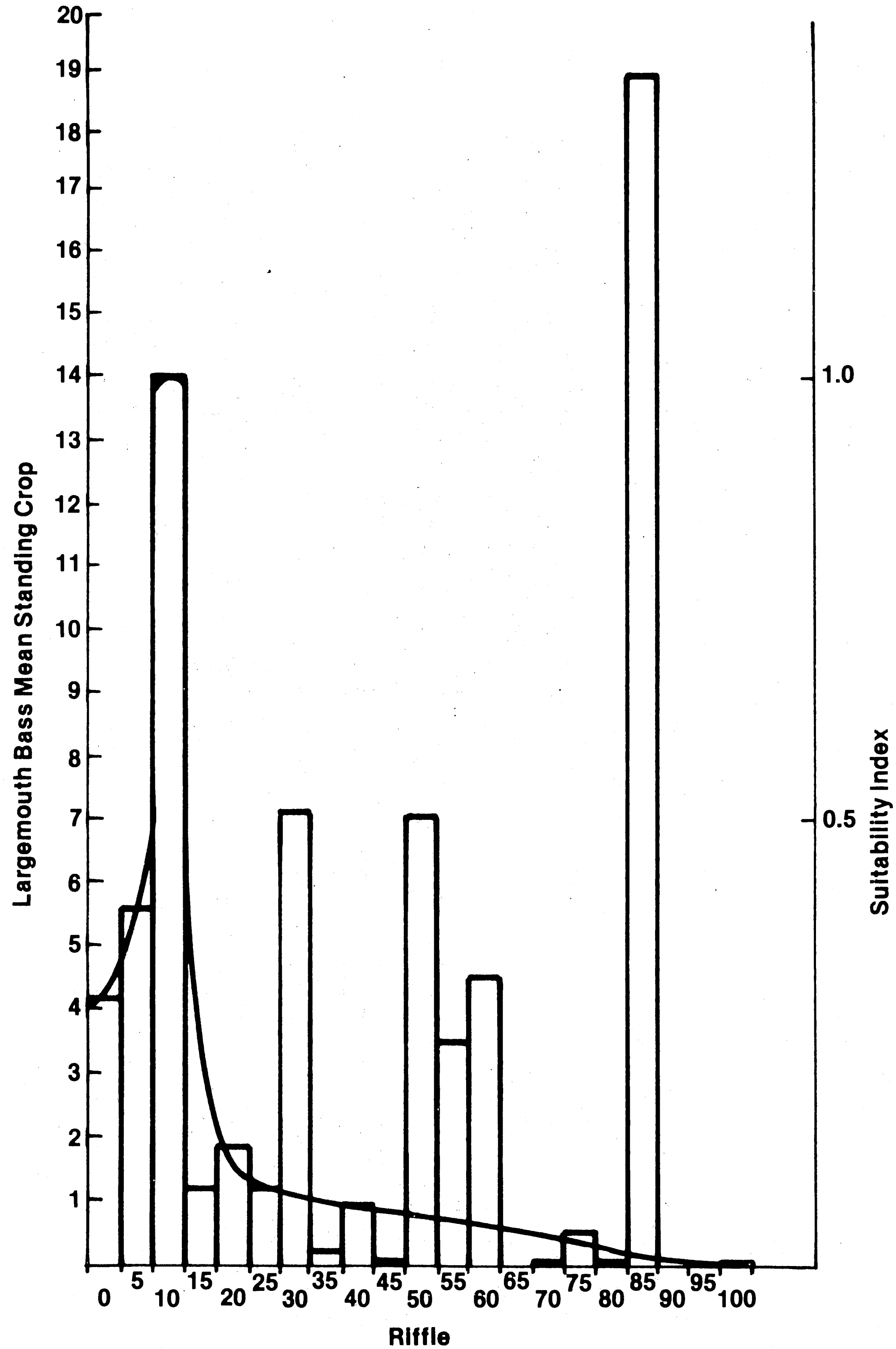


Figure 113. Relationship between largemouth bass mean standing crop (kg/ha) and percent riffle.

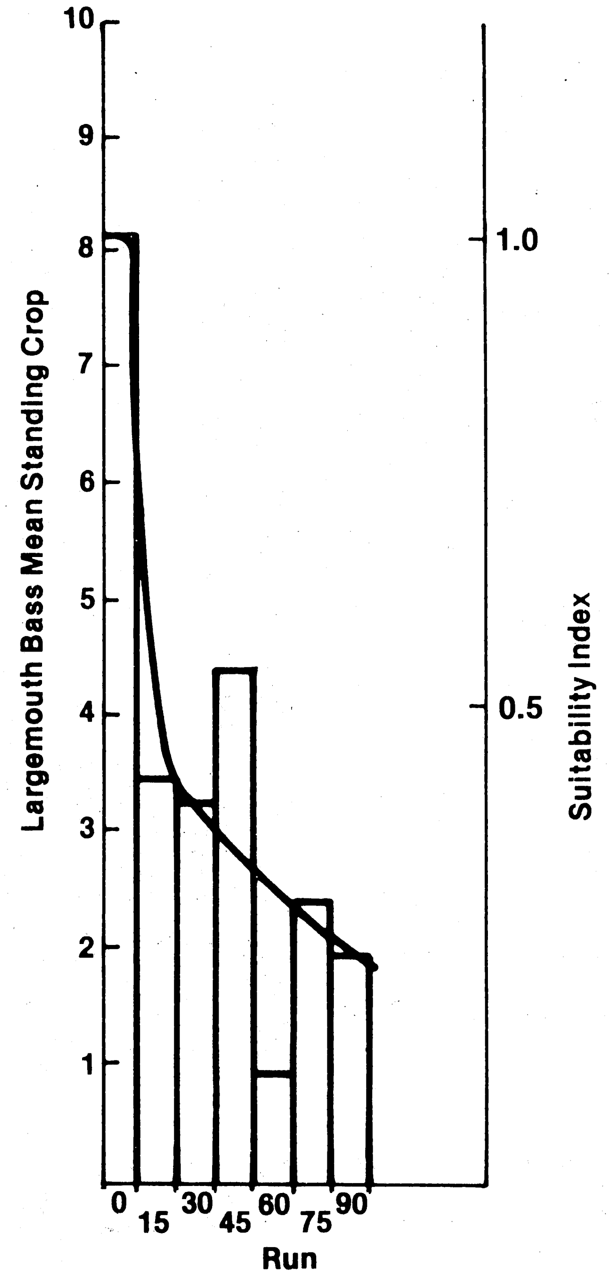


Figure 114. Relationship between largemouth bass mean standing crop (kg/ha) and percent run.

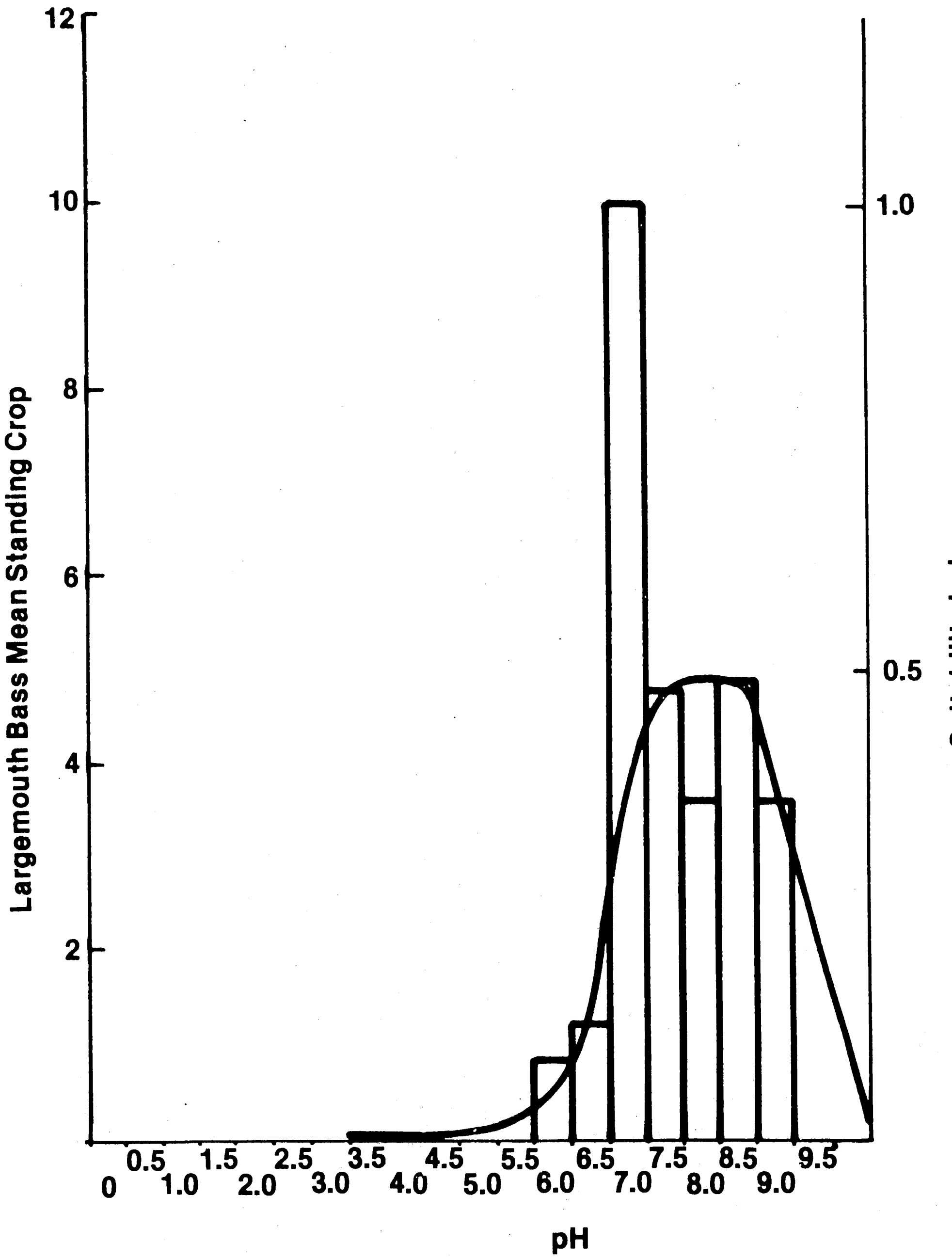


Figure 115. Relationship between largemouth bass mean standing crop (kg/ha) and pH.

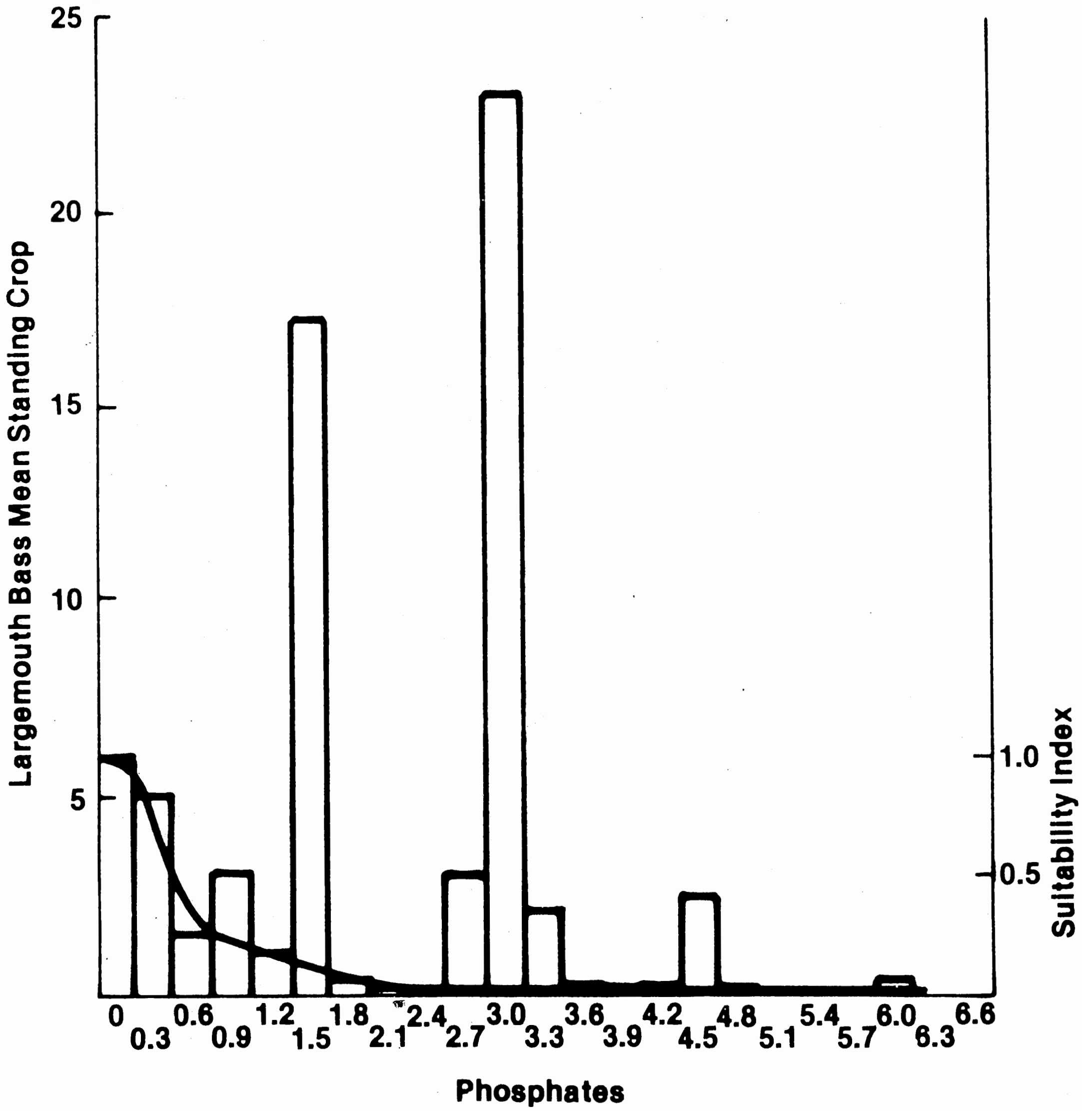


Figure 116. Relationship between largemouth bass mean standing crop (kg/ha) and phosphates (mg/l).

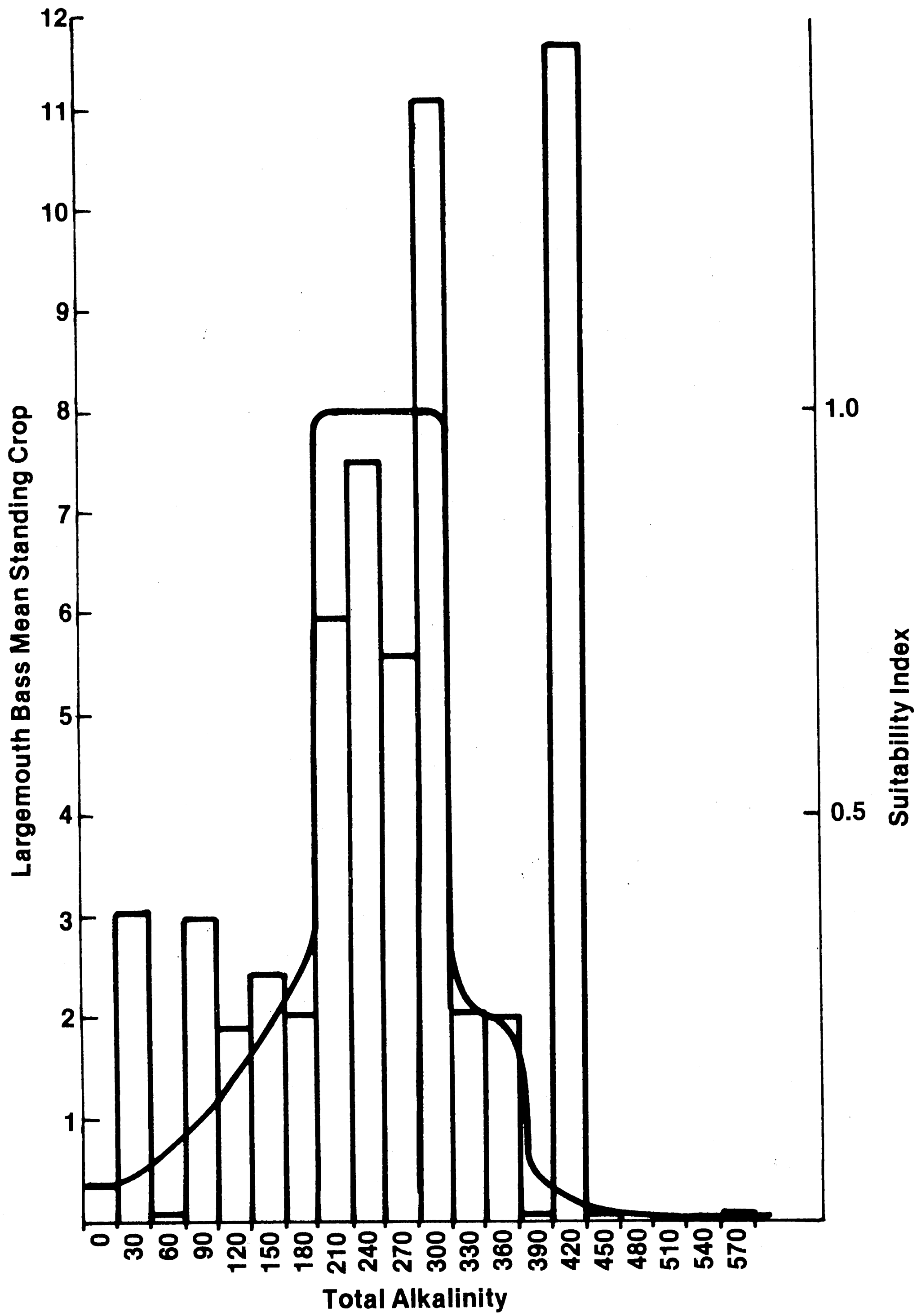


Figure 117. Relationship between largemouth bass mean standing crop (kg/ha) and total alkalinity (mg/l).

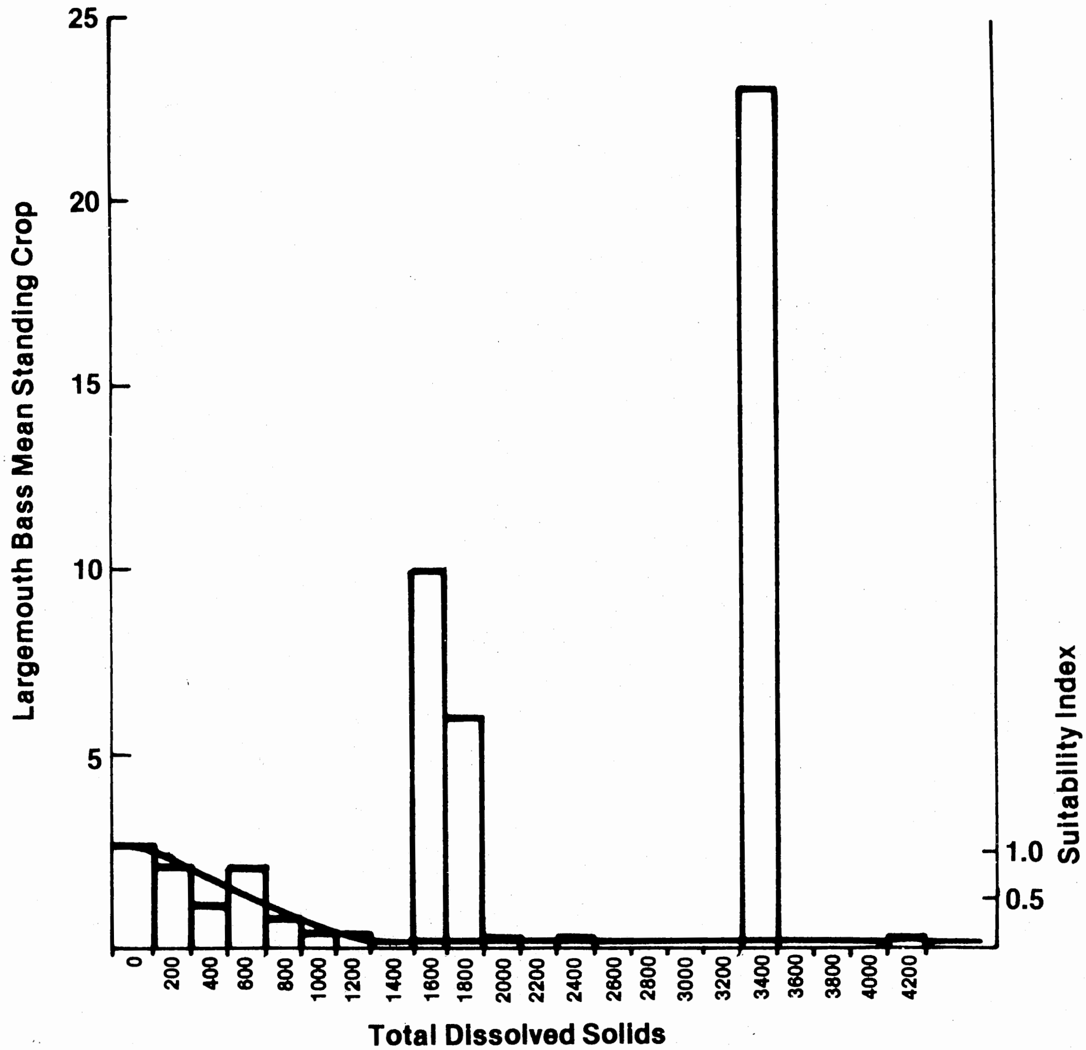


Figure 118. Relationship between largemouth bass mean standing crop (kg/ha) and total dissolved solids (mg/l).

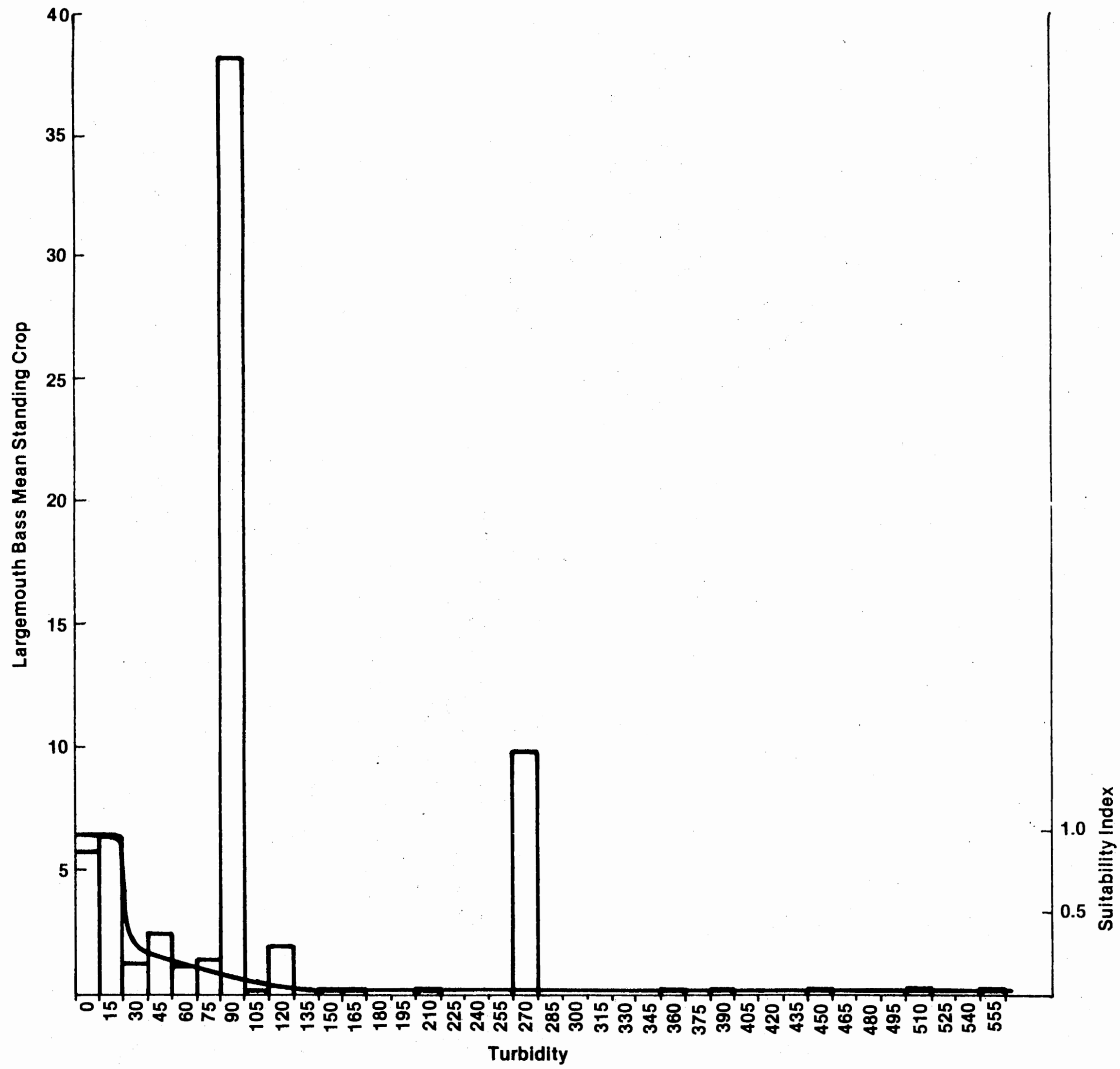


Figure 119. Relationship between largemouth bass mean standing crop (kg/ha) and turbidity (JTU's).

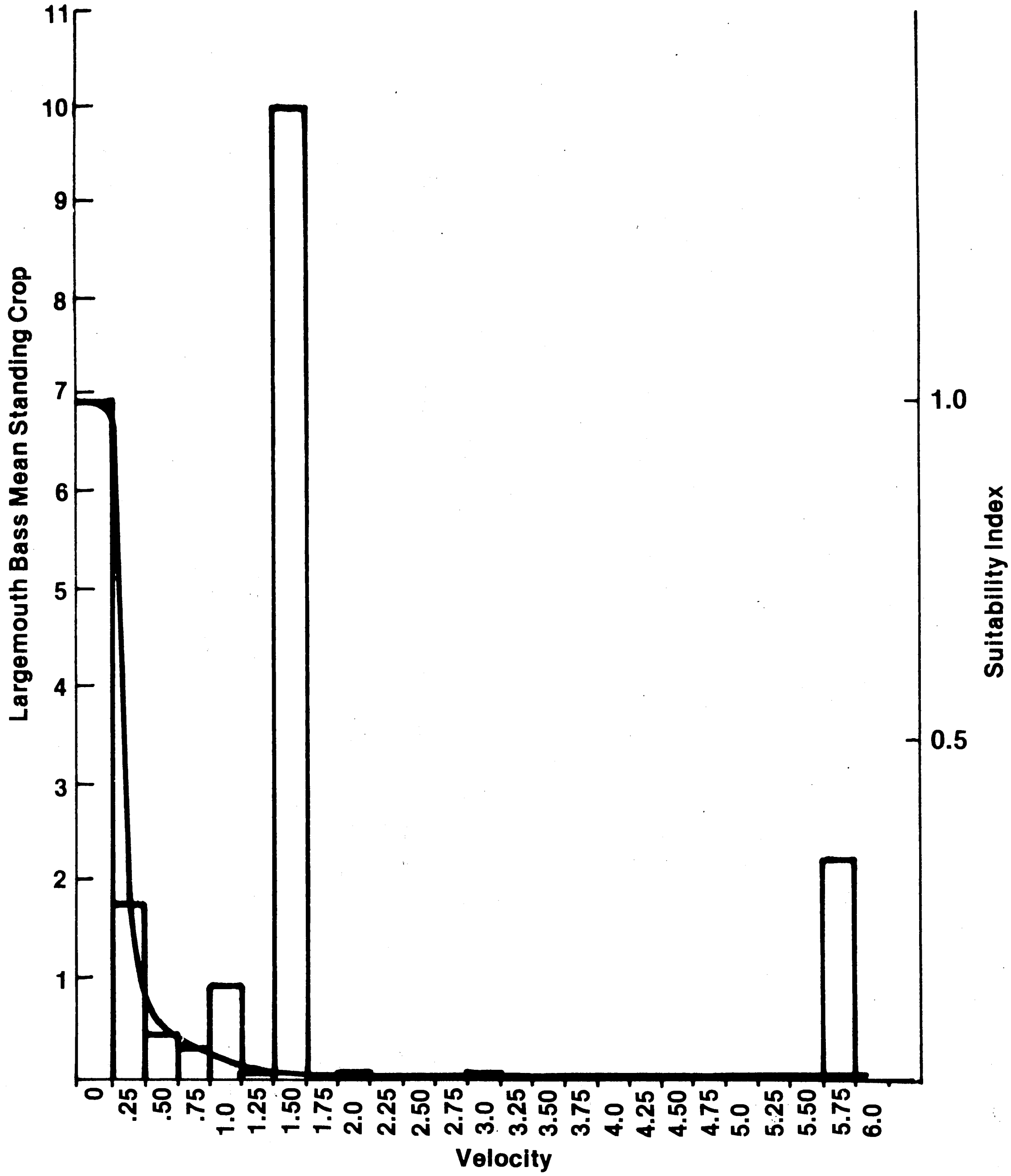


Figure 120. Relationship between largemouth bass mean standing crop (kg/ha) and velocity (m/s).

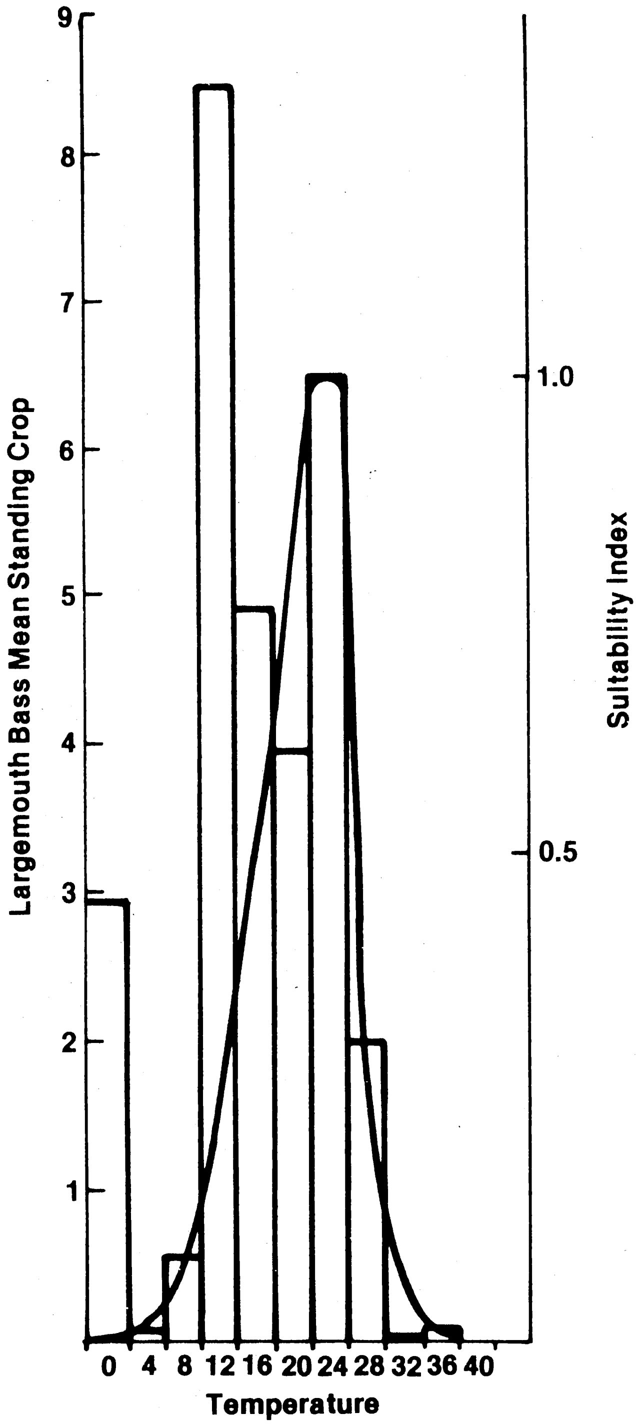


Figure 121. Relationship between large-mouth bass mean standing crop (kg/ha) and water temperature (C).

## APPENDIX G

## WHITE CRAPPIE SUITABILITY CURVES (INTERVAL RANGES, MEANS, AND N VALUES GIVEN IN APPENDIX I)

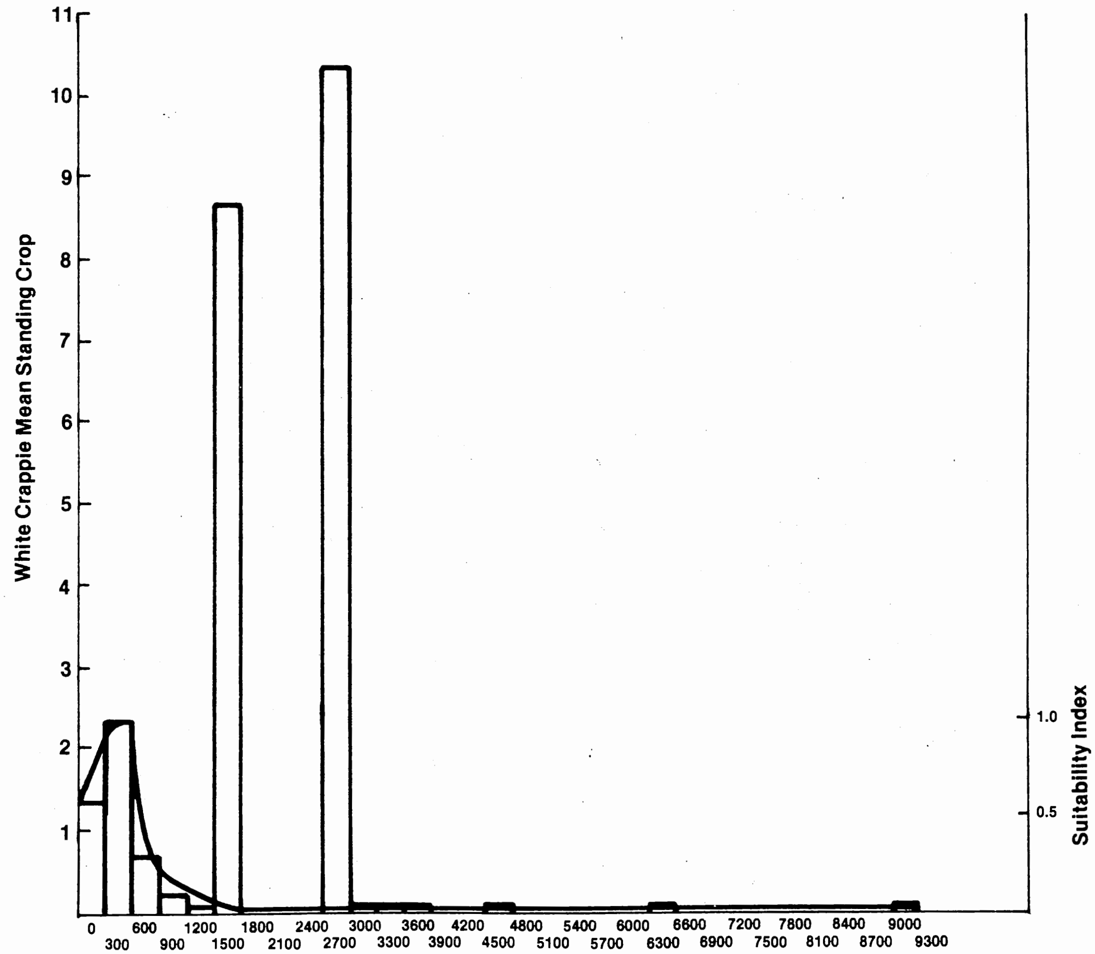


Figure 122. Relationship between white crappie mean standing crop (ka/ha) and conductivity (μmhos/cm).

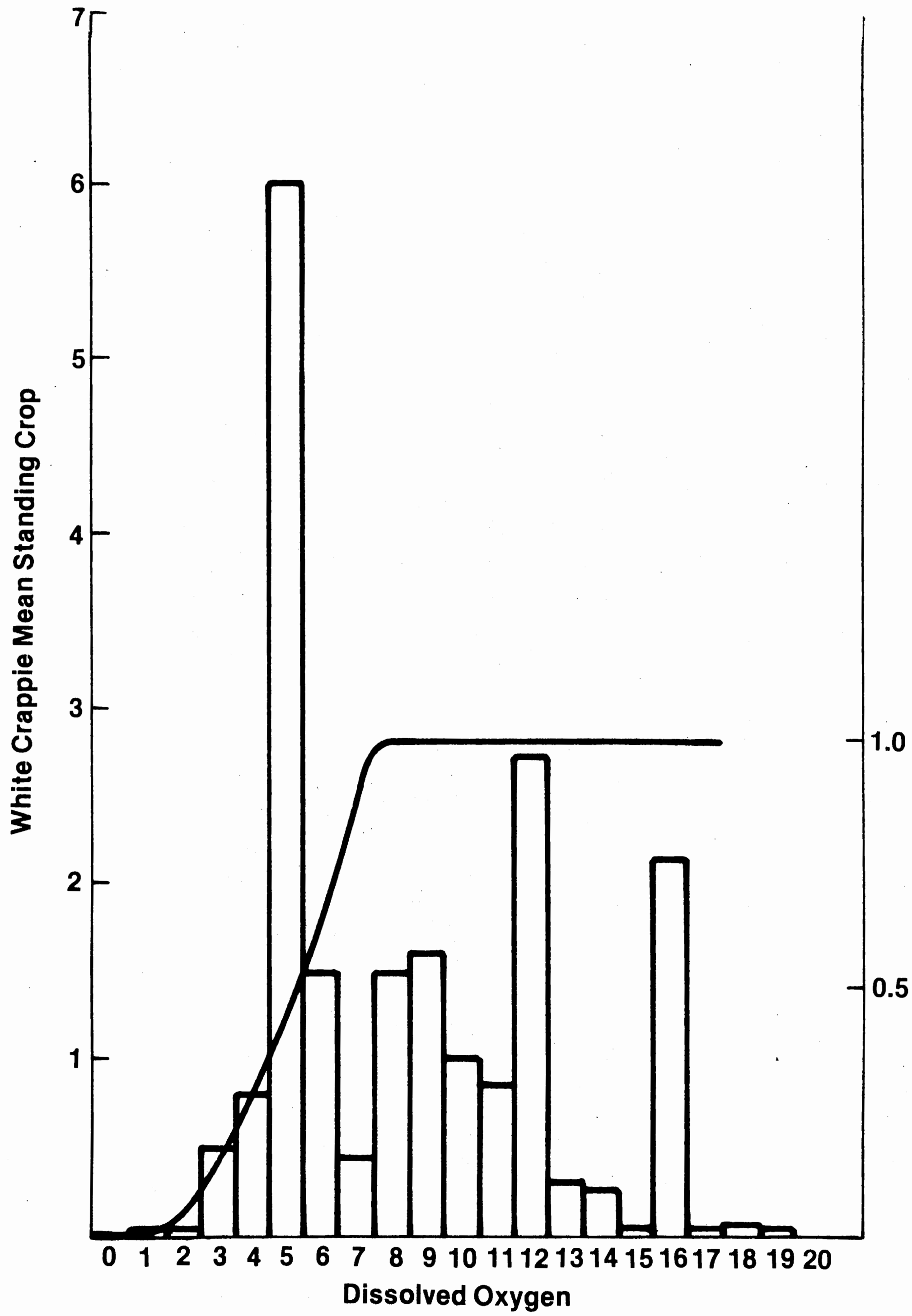


Figure 123. Relationship between white crappie mean standing crop (ka/ha) and dissolved oxygen (mg/l).

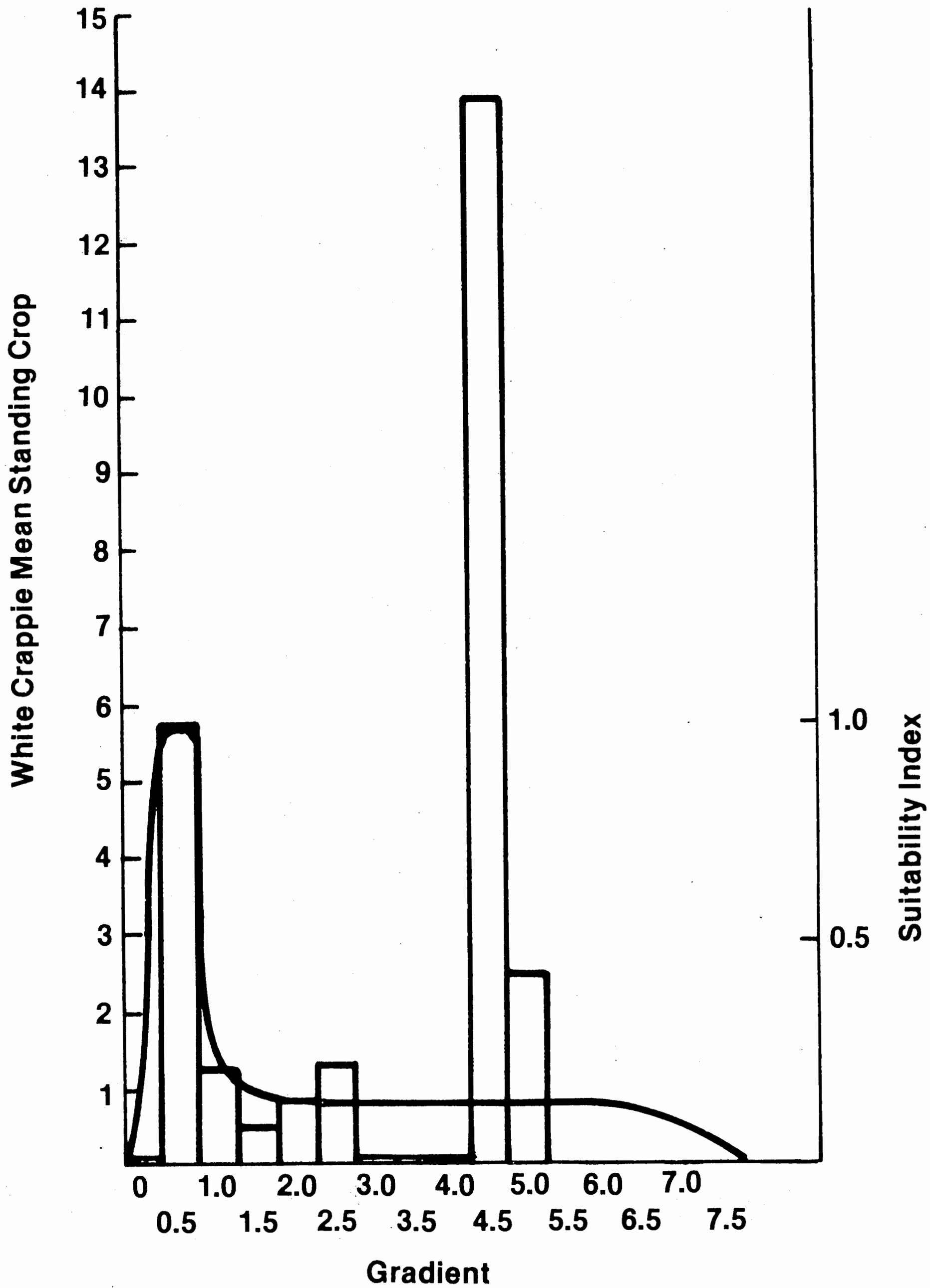


Figure 124. Relationship between white crappie mean standing crop (kg/ha) and gradient (m/km).

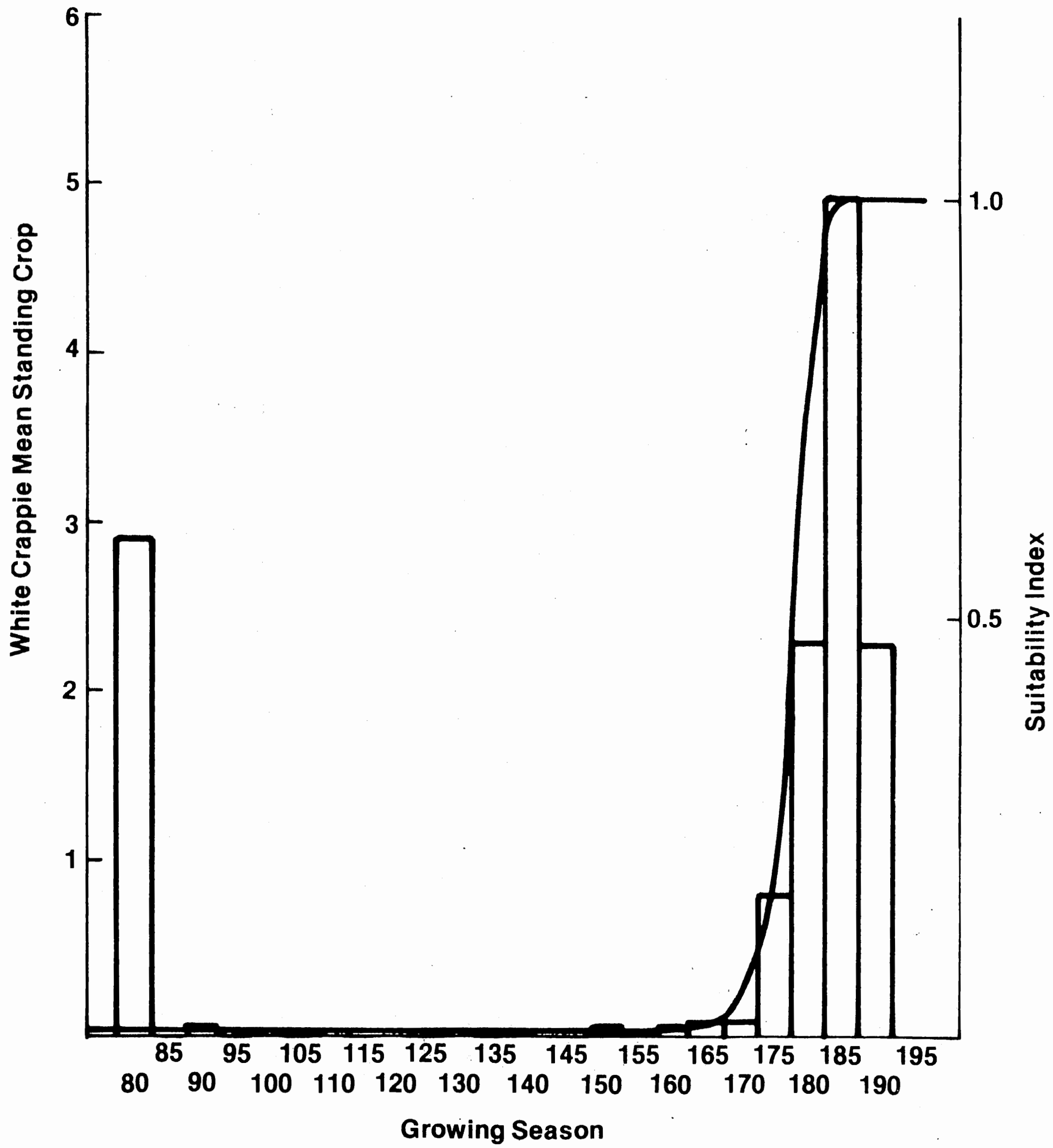


Figure 125. Relationship between white crappie mean standing crop (kg/ha) and growing season (frost-free days).

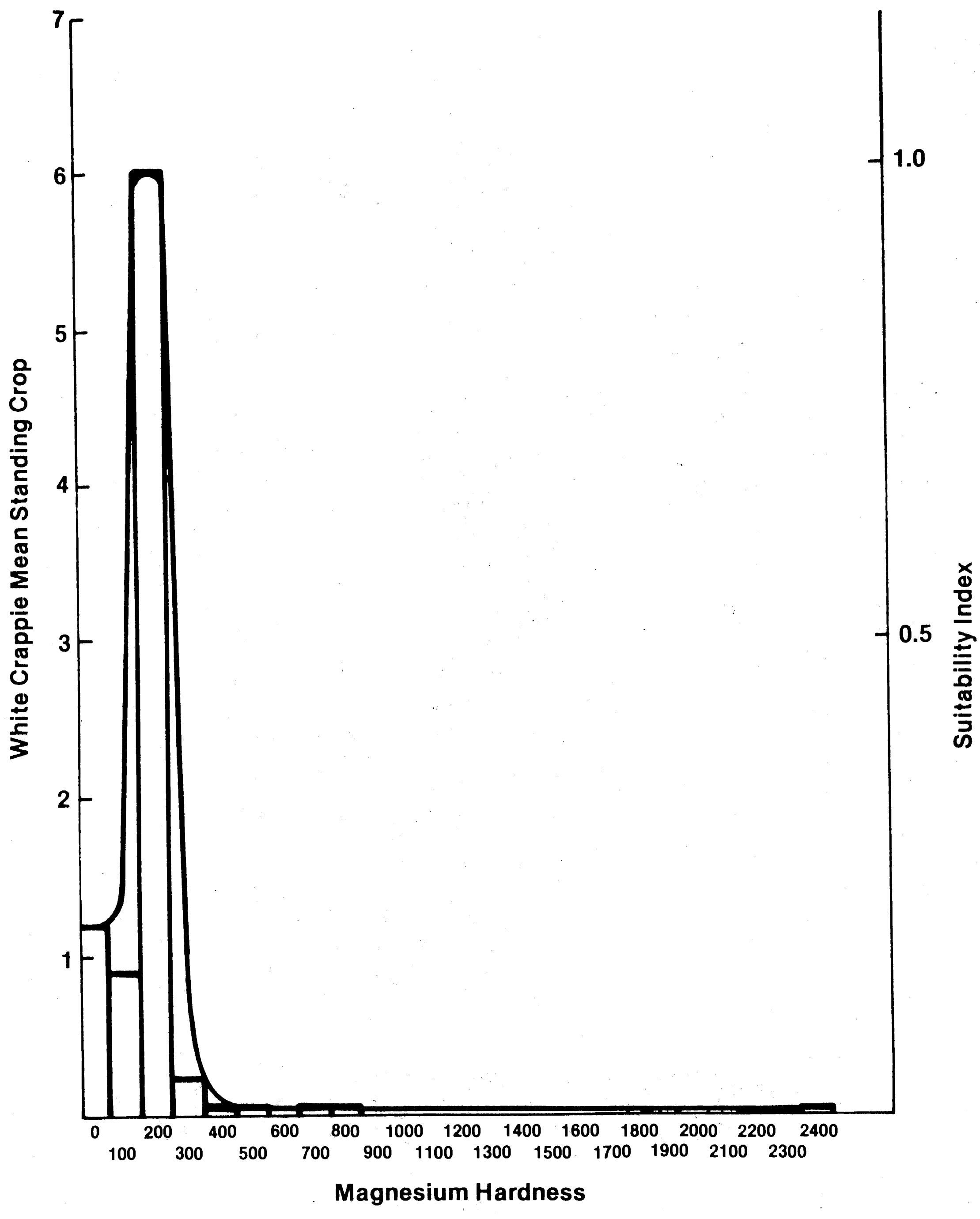


Figure 126. Relationship between white crappie mean standing crop (kg/ha) and magnesium hardness (mg/l).

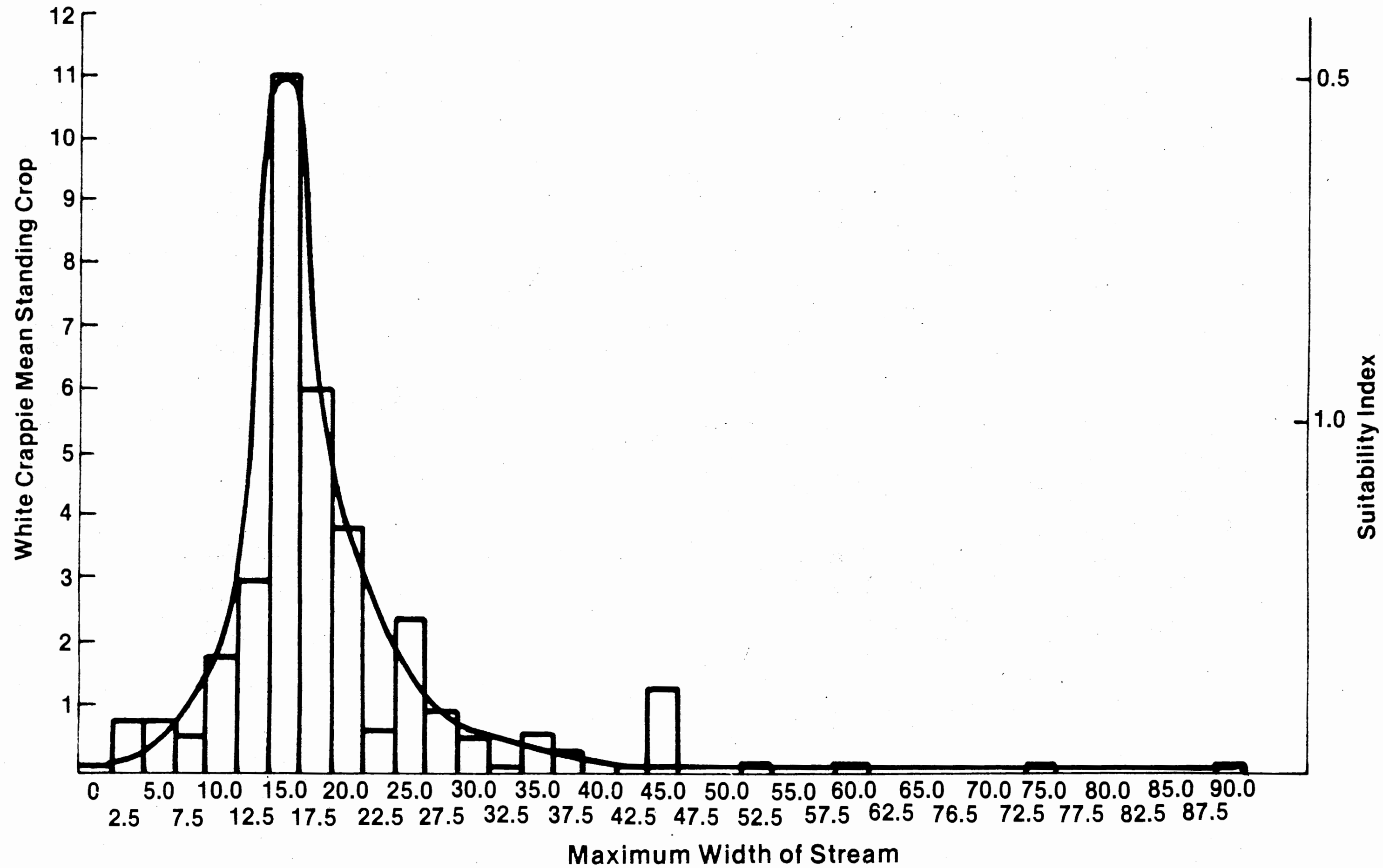


Figure 127. Relationship between white crappie mean standing crop (kg/ha) and maximum stream width (m).

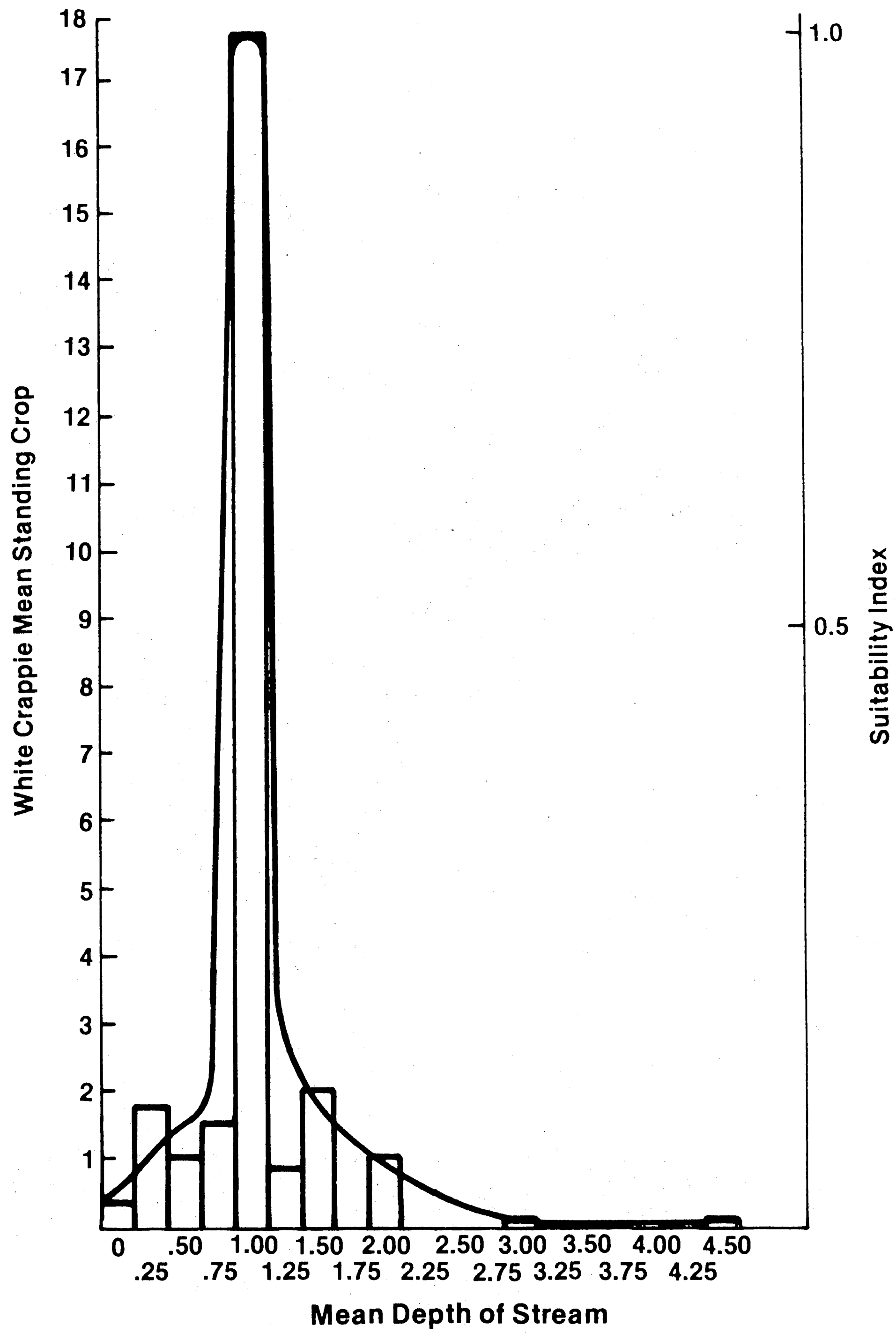


Figure 128. Relationship between white crappie mean standing crop (kg/ha) and mean stream depth (m).

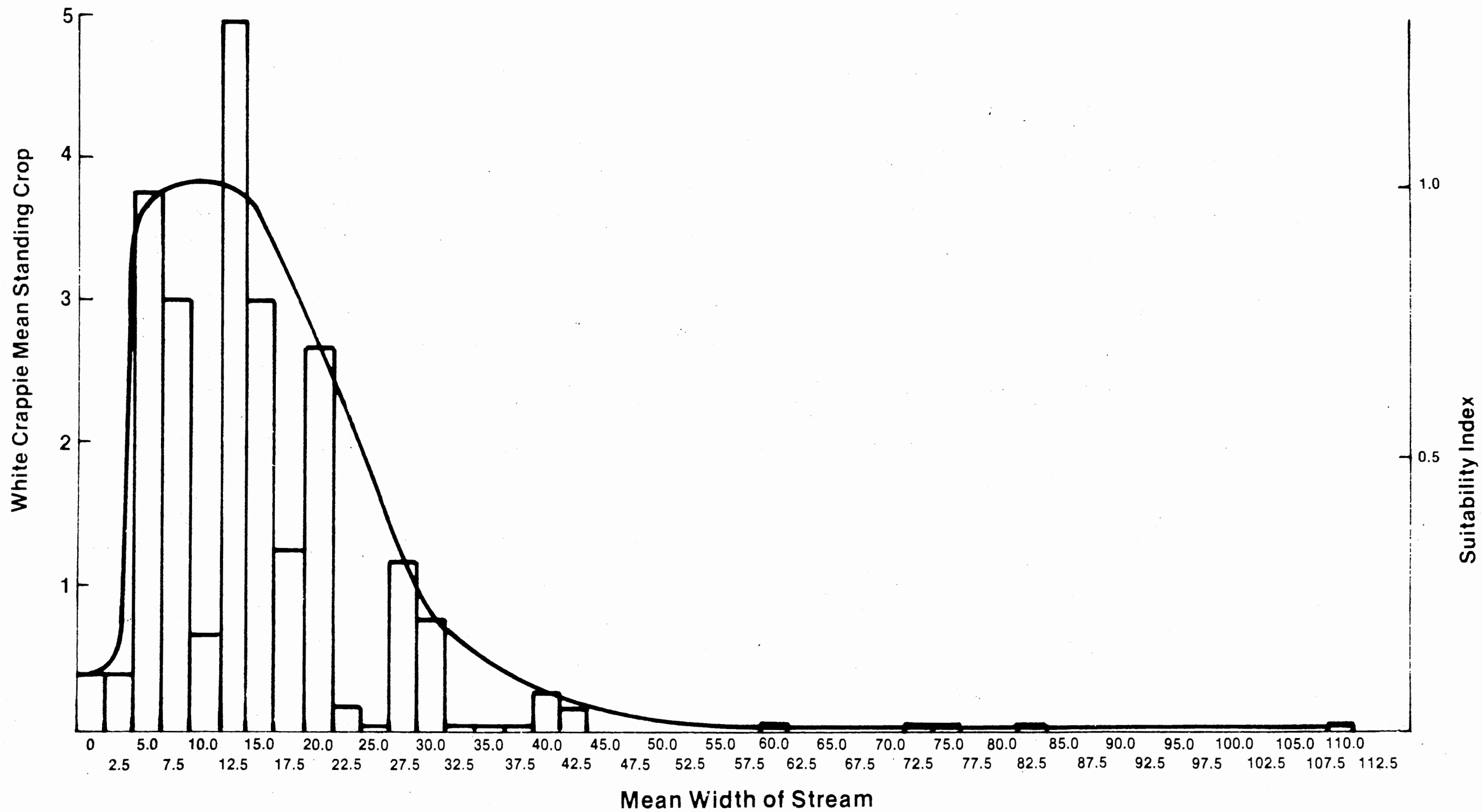


Figure 129. Relationship between white crappie mean standing crop (kg/ha) and mean stream width (m).

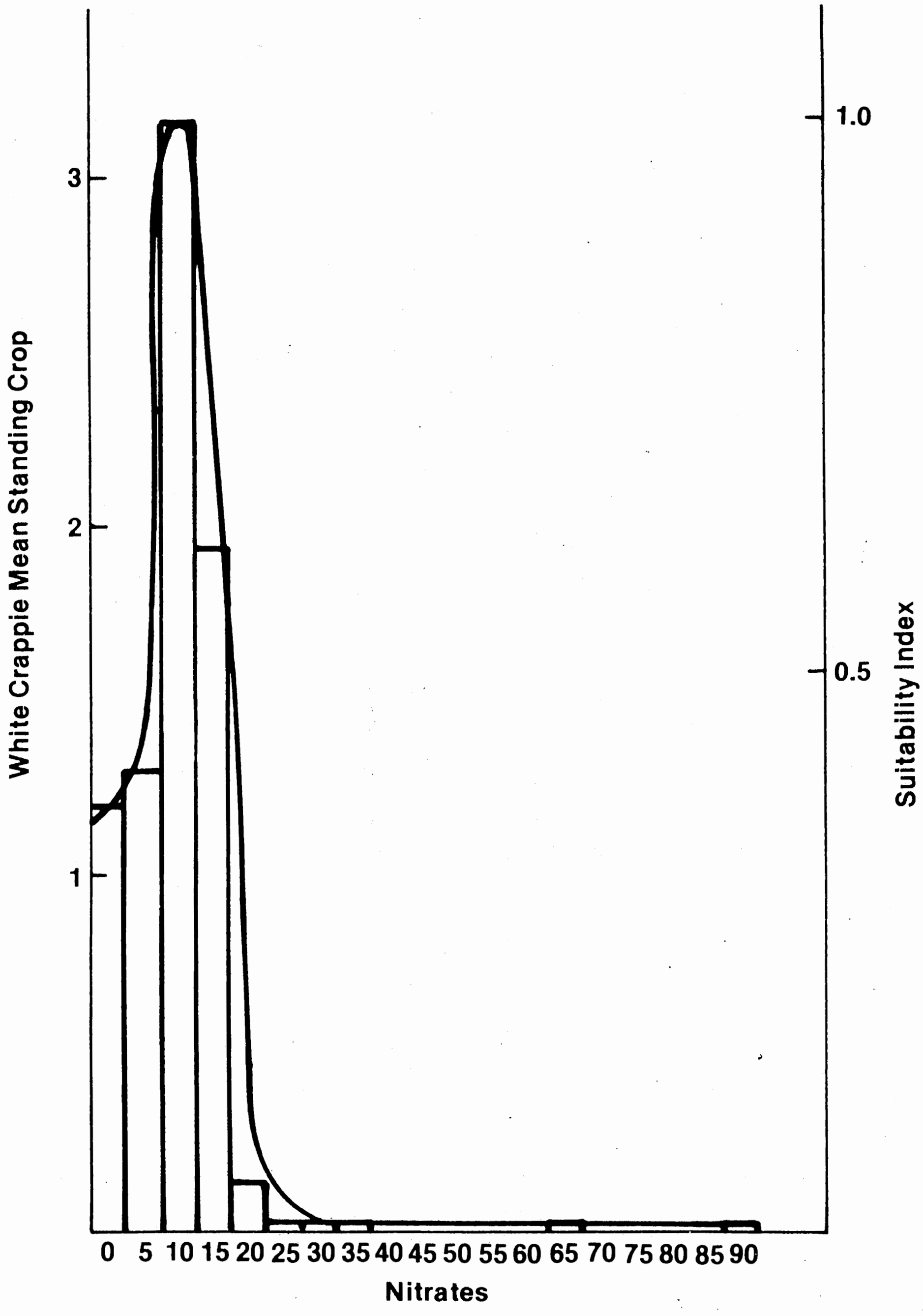


Figure 130. Relationship between white crappie mean standing crop (kg/ha) and nitrates (mg/l).

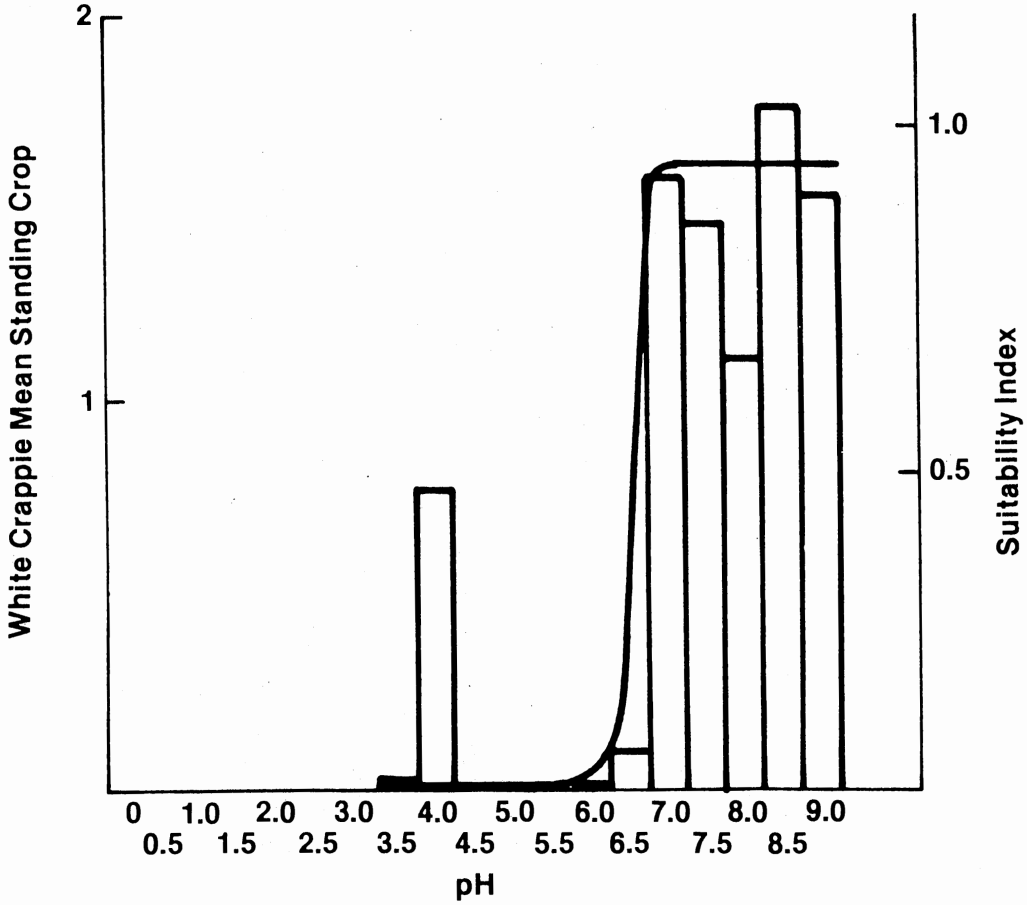


Figure 131. Relationship between white crappie mean standing crop (kg/ha) and pH.

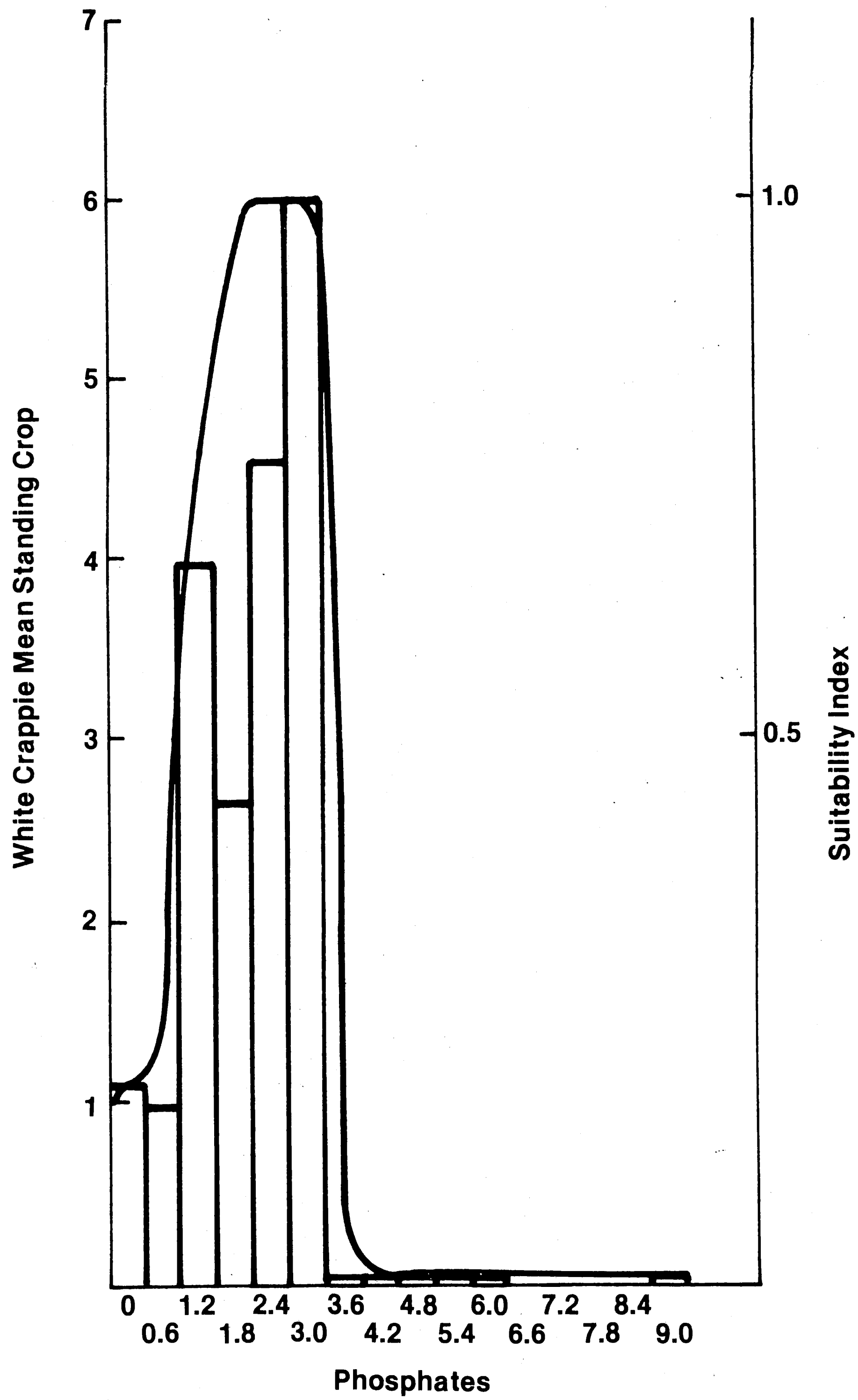


Figure 132. Relationship between white crappie mean standing crop (kg/ha) and phosphates (mg/l).

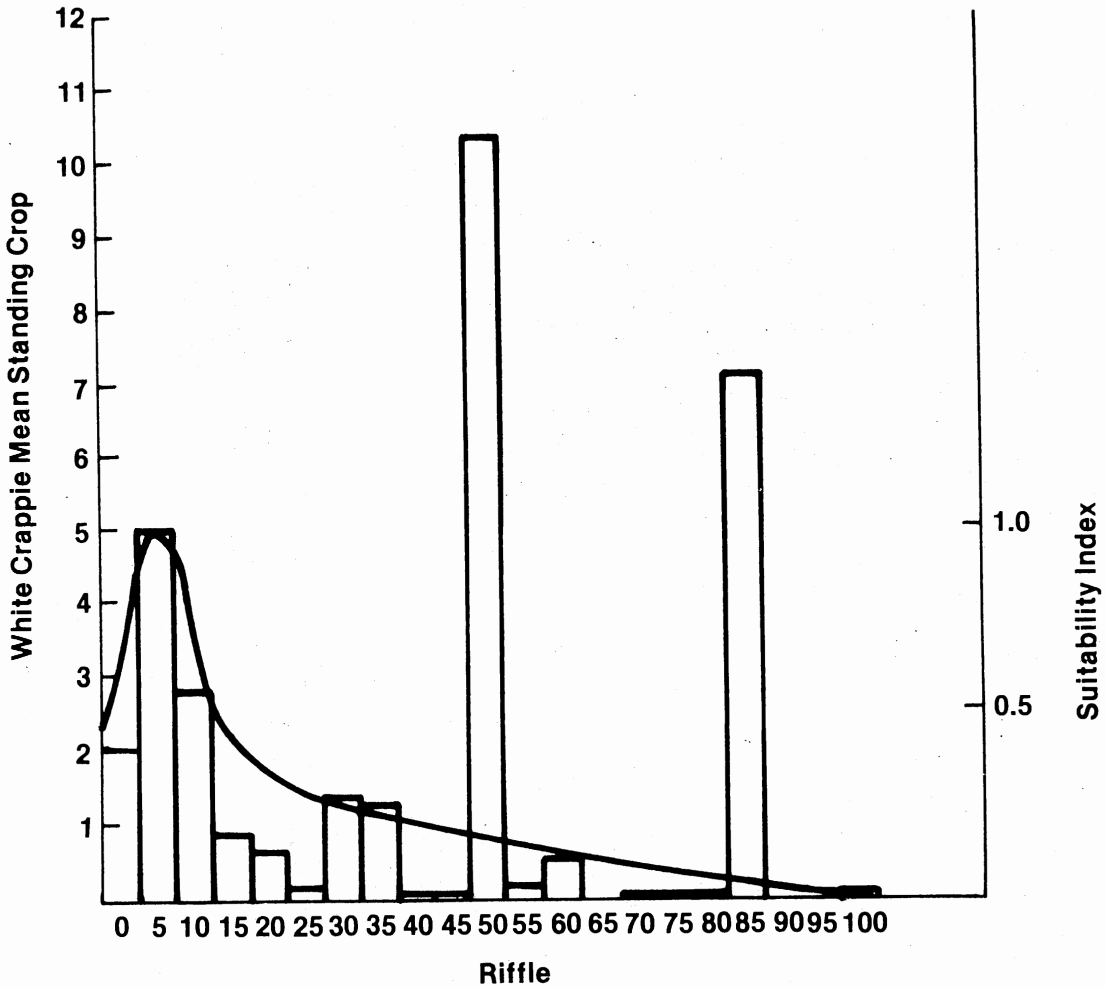


Figure 133. Relationship between white crappie mean standing crop (kg/ha) and percent riffle.

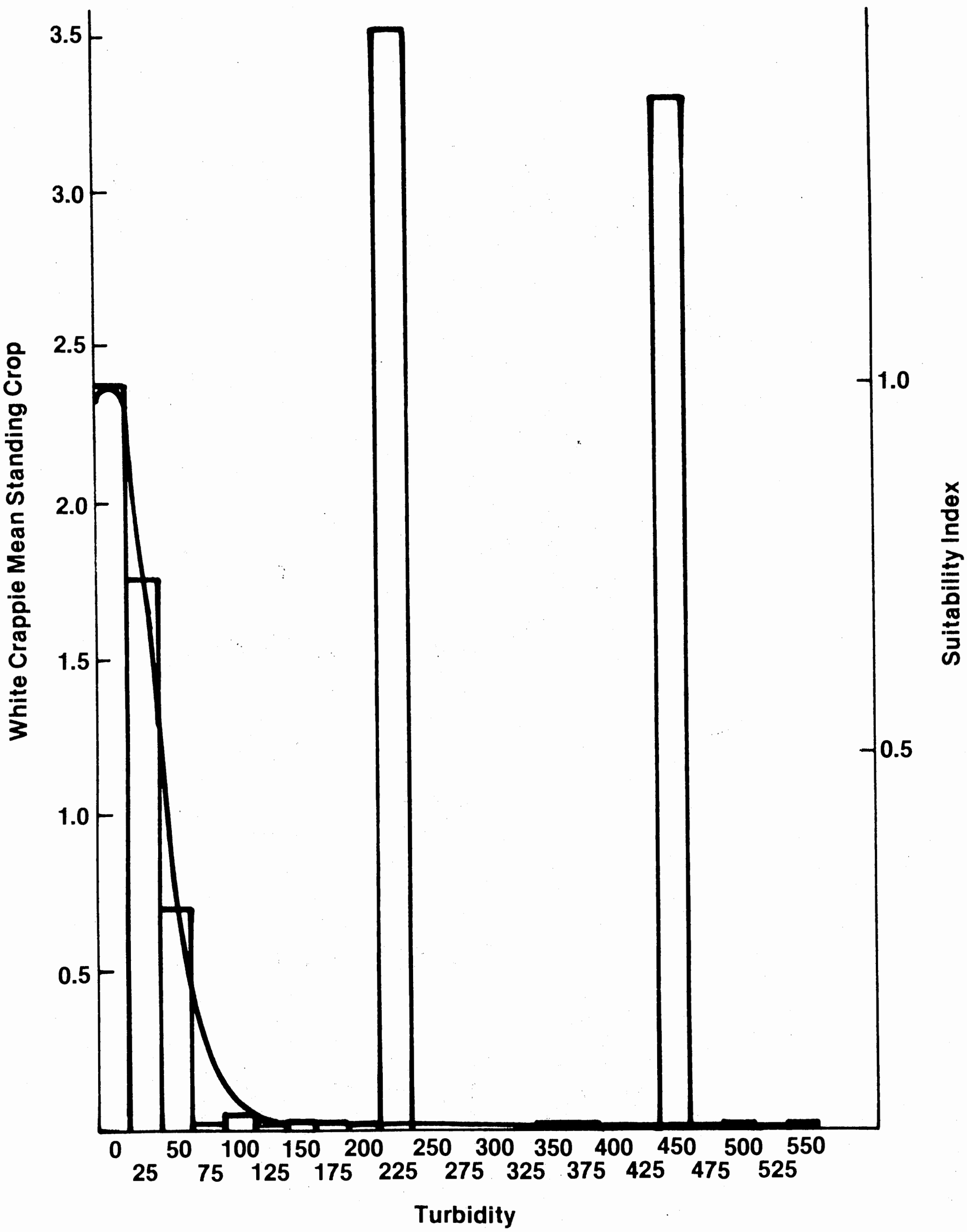


Figure 134. Relationship between white crappie mean standing crop (kg/ha) and turbidity (JTU's).

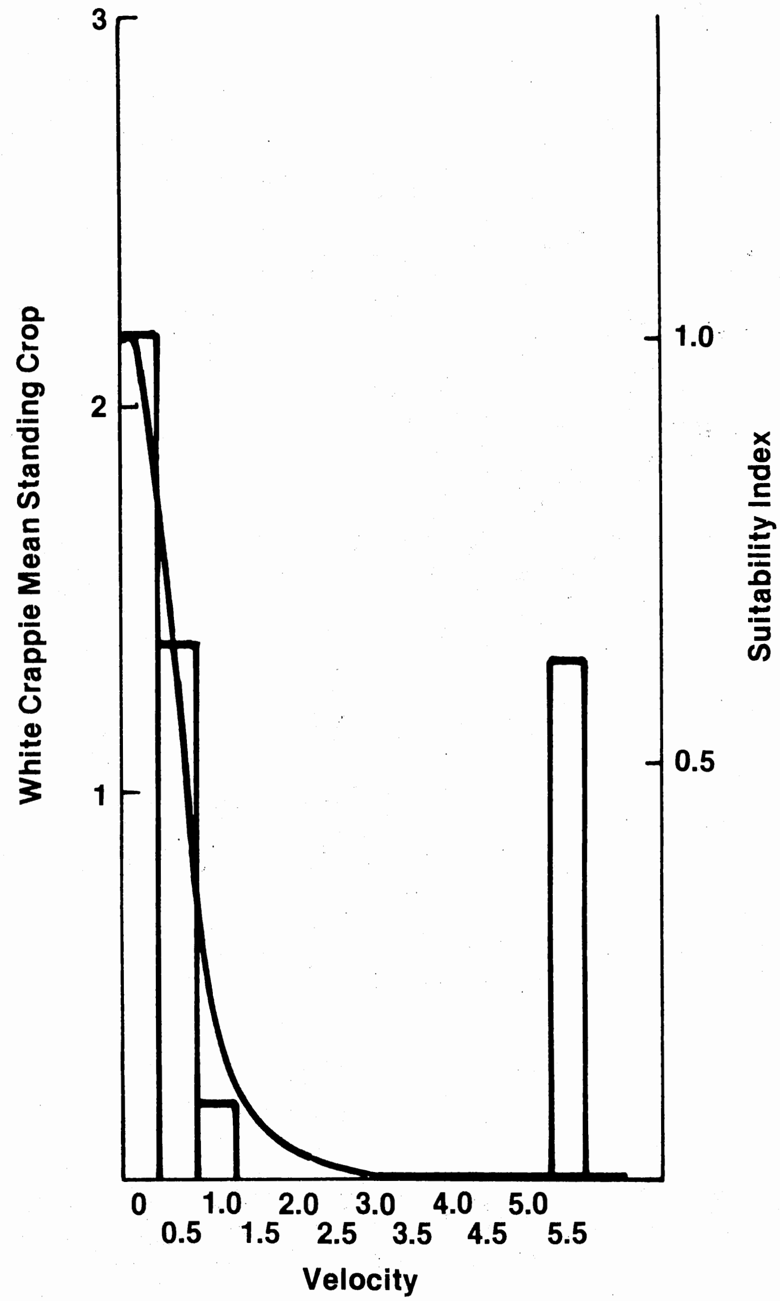


Figure 135. Relationship between white crappie mean standing crop (kg/ha) and velocity (m/s).

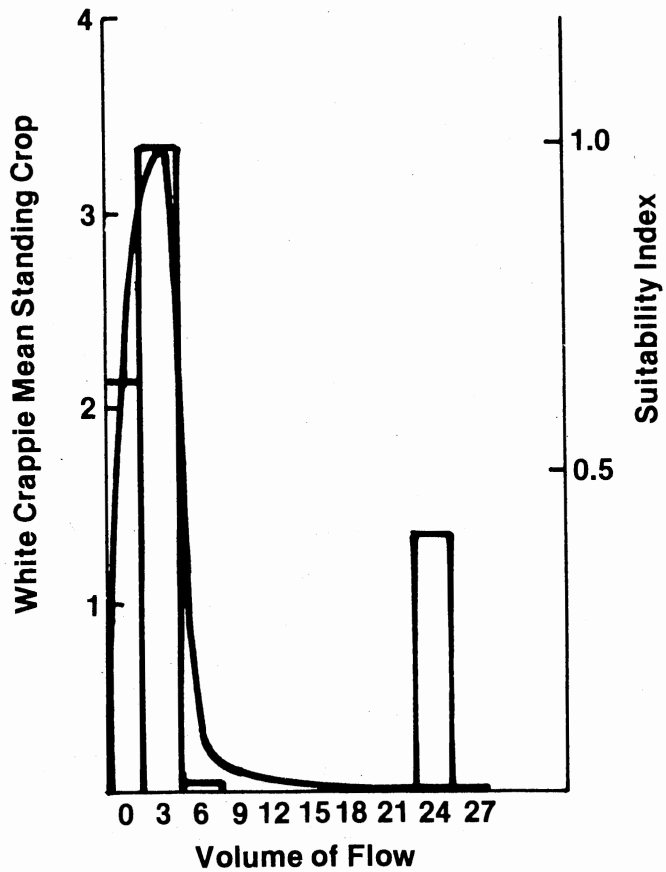


Figure 136. Relationship between white crappie mean standing crop (kg/ha) and volume of flow ($m^3/s$).

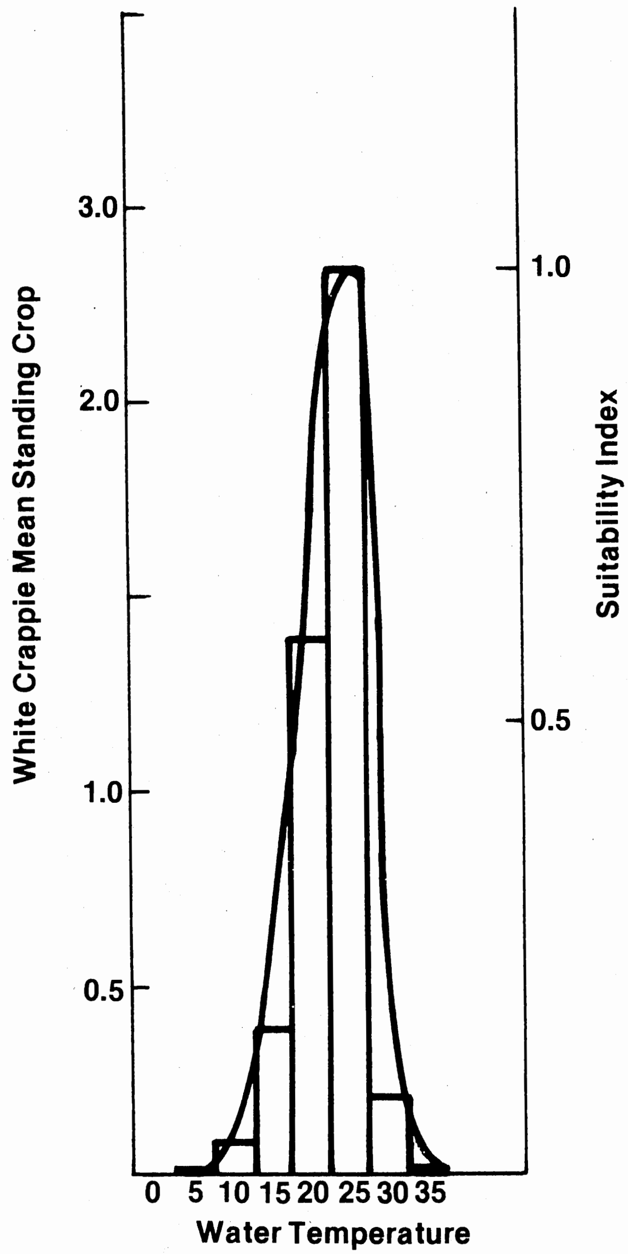


Figure 137. Relationship between white crappie mean standing crop (kg/ha) and water temperature (C).

# APPENDIX H

## GREEN SUNFISH SUITABILITY CURVES (INTERVAL RANGES, MEANS, AND N VALUES GIVEN IN APPENDIX I)

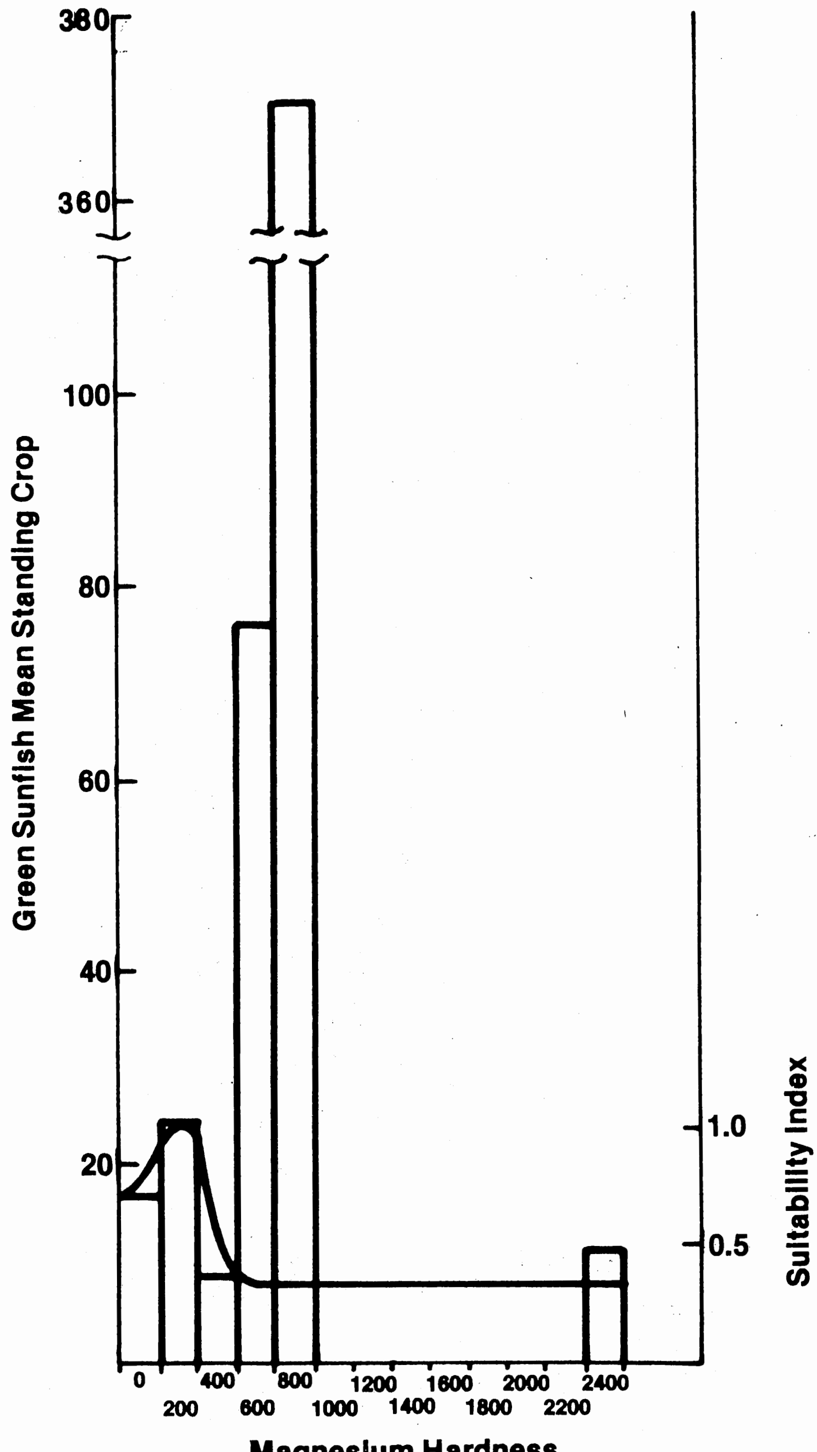


Figure 138. Relationship between green sunfish mean standing crop (kg/ha) and magnesium hardness (mg/l).

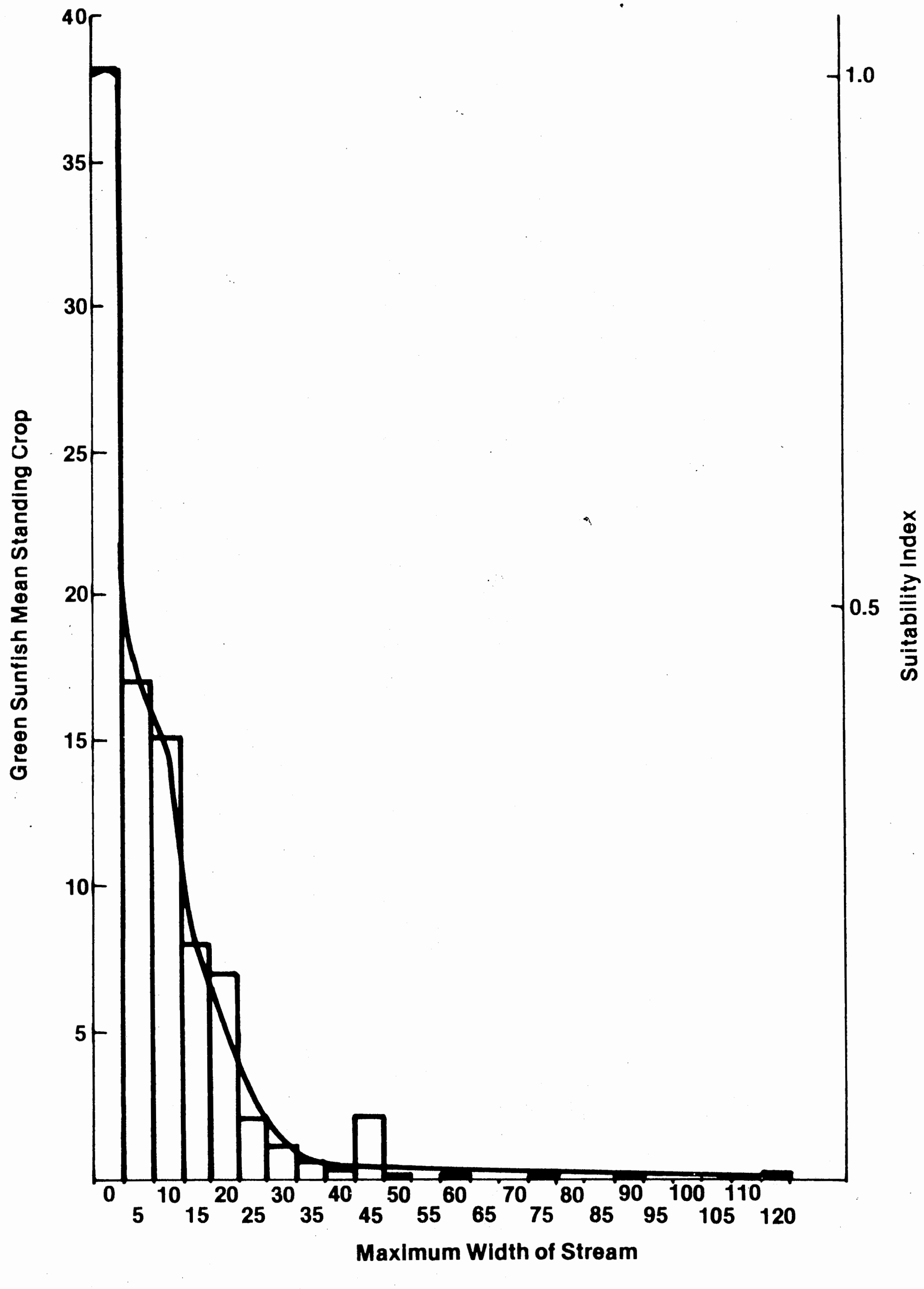


Figure 139. Relationship between green sunfish mean standing crop (kg/ha) and maximum stream width (m).

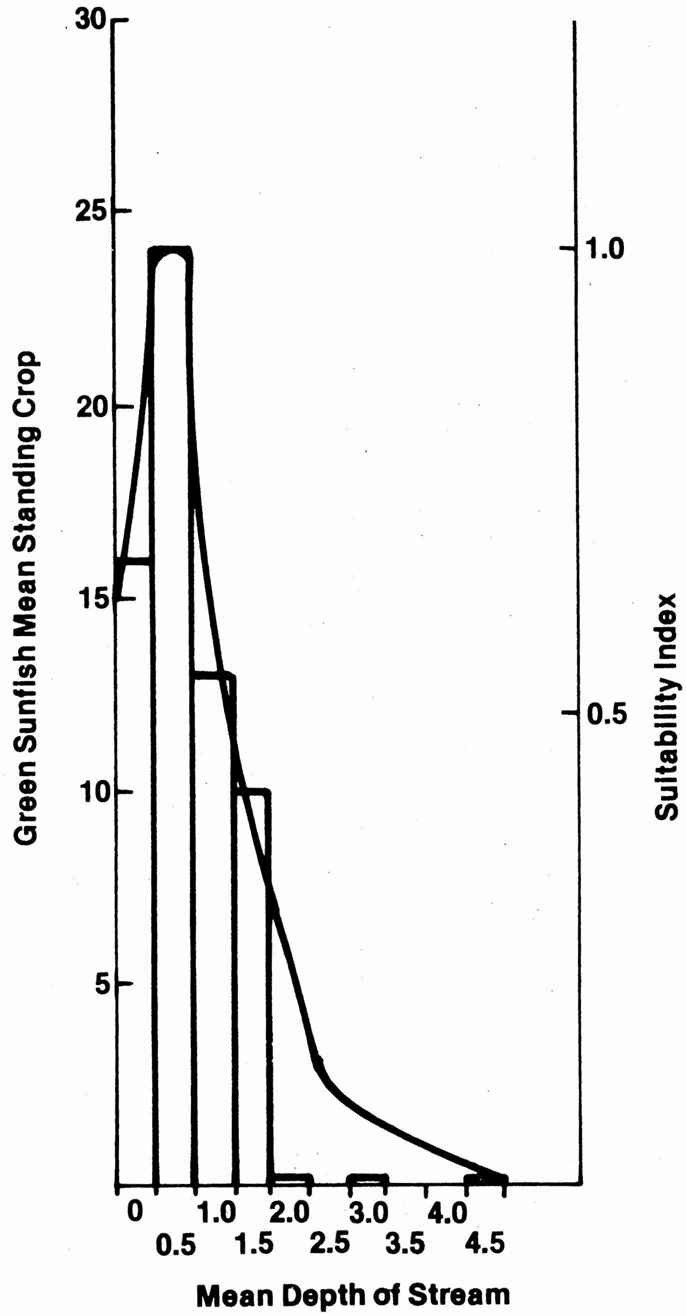


Figure 140. Relationship between green sunfish mean standing crop (kg/ha) and mean stream depth (m).

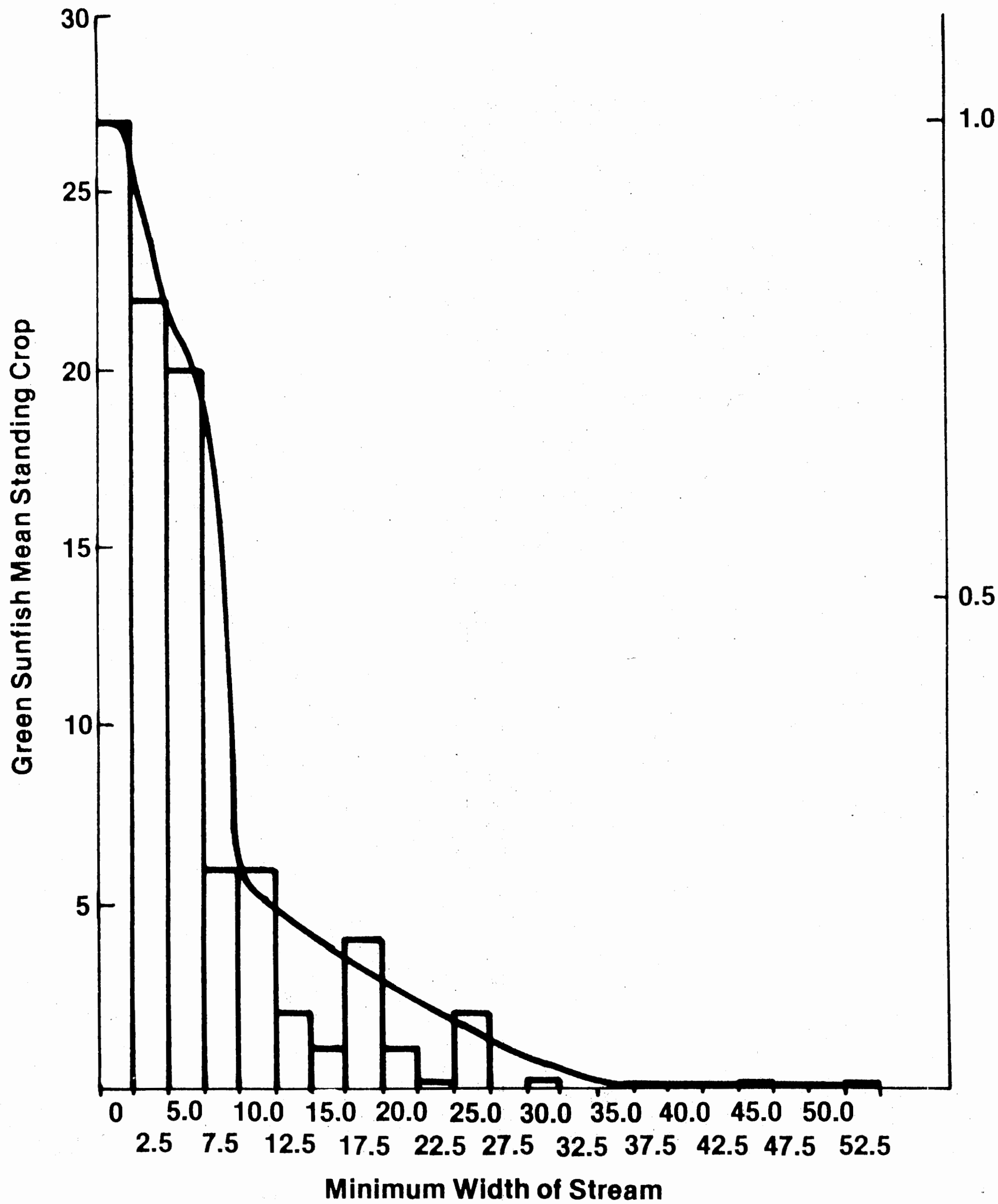


Figure 141. Relationship between green sunfish mean standing crop (kg/ha) and minimum stream width (m).

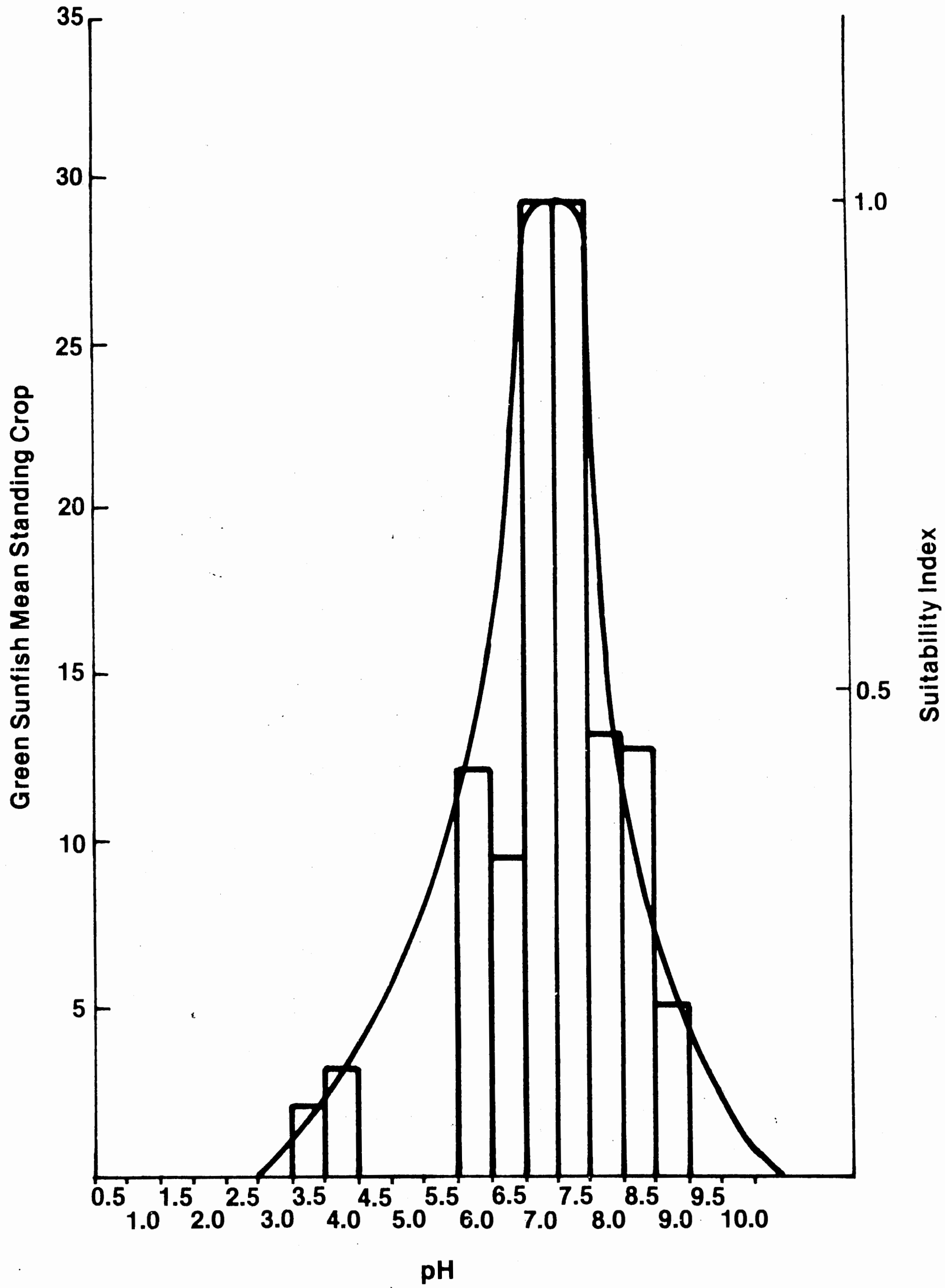


Figure 142. Relationship between green sunfish mean standing crop (kg/ha) and pH.

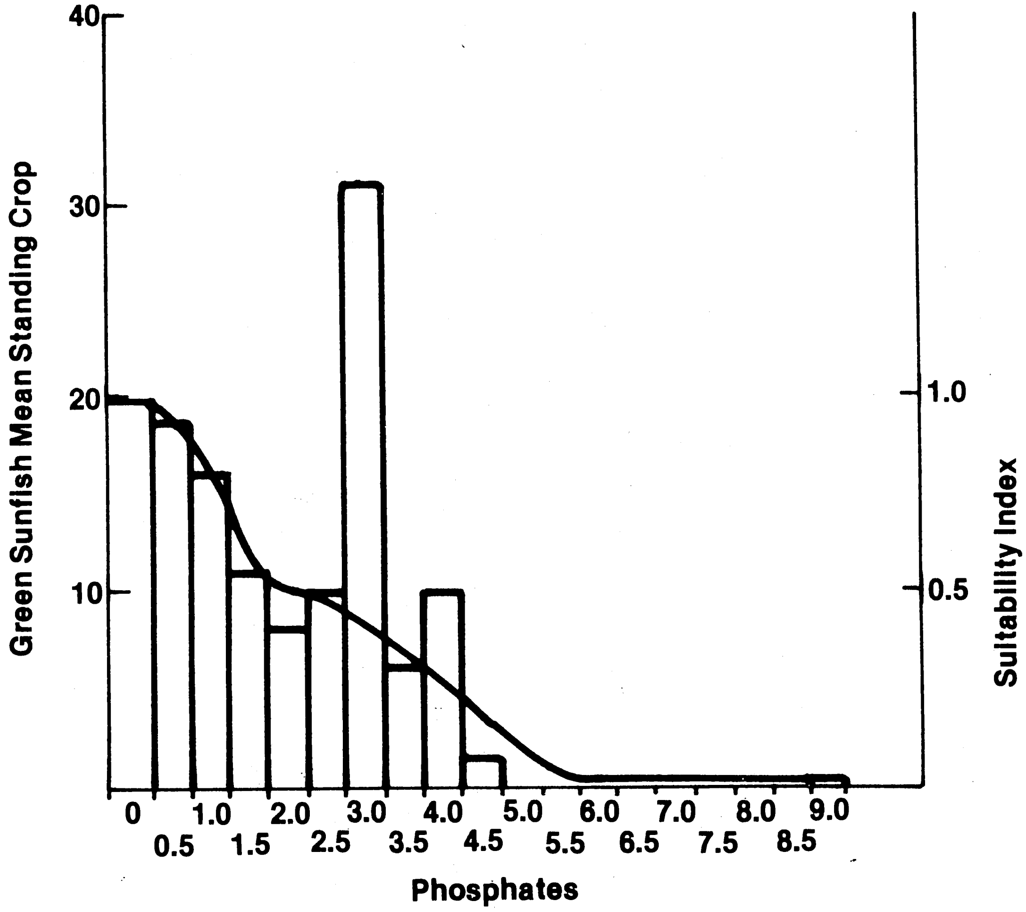


Figure 143. Relationship between green sunfish mean standing crop (kg/ha) and phosphates (mg/1).

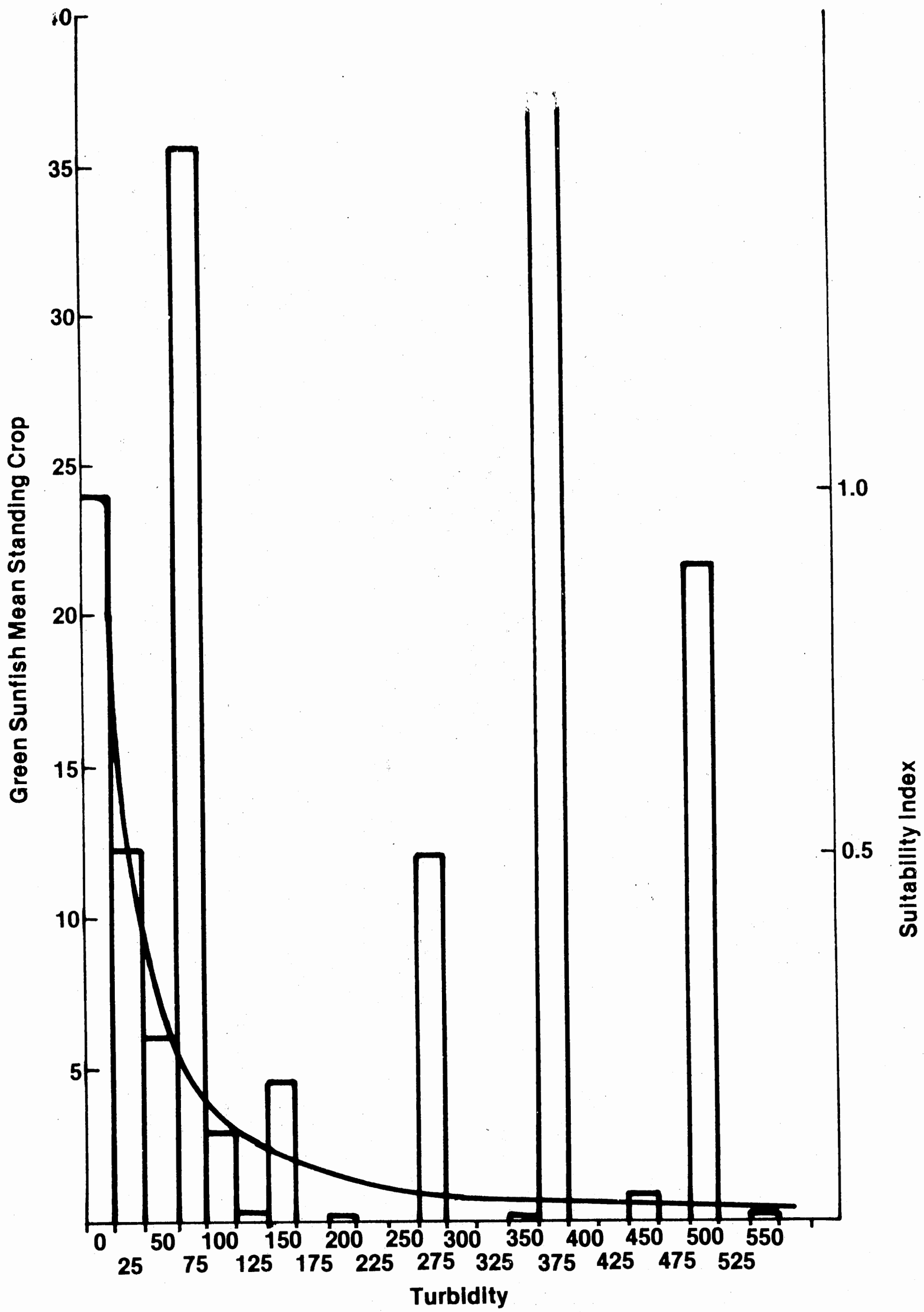


Figure 144. Relationship between green sunfish mean standing crop (kg/ha) and turbidity (JTU's).

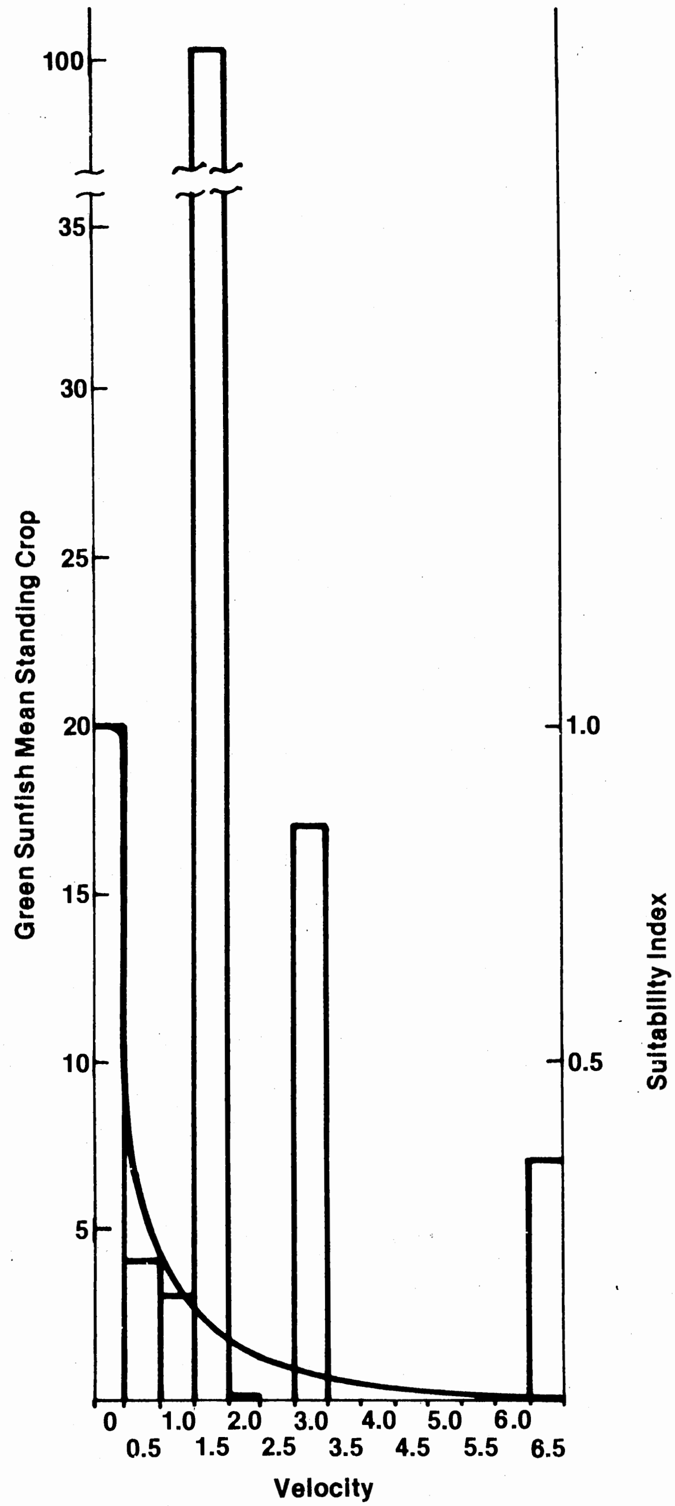


Figure 145. Relationship between green sunfish mean standing crop (kg/ha) and velocity (m/s).

## APPENDIX I

## DATA ON WHICH SUITABILITY CURVES WERE BASED, BY SPECIES AND STREAM CHARACTERISTICS

Table 22. Mean standing crop values by species for increments of physical and chemical variables for parameters for which suitability curves were drawn.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | mean depth | 0.0 | 0.6 | 275 | 0.92 |
| | | 0.6 | 1.2 | 128 | 0.57 |
| | | 1.2 | 1.8 | 14 | 9.55 |
| | | 1.8 | 2.4 | 1 | 0.00 |
| | | 3.0 | 3.6 | 1 | 0.56 |
| | | 4.2 | 4.8 | 1 | 0.00 |
| | mean width | 0 | 10 | 303 | 0.46 |
| | | 10 | 20 | 85 | 3.18 |
| | | 20 | 30 | 15 | 2.89 |
| | | 30 | 40 | 9 | 0.77 |
| | | 40 | 50 | 2 | 0.05 |
| | | 50 | 60 | 1 | 0.00 |
| | | 60 | 70 | 2 | 0.00 |
| | | 70 | 80 | 1 | 0.00 |
| | | 80 | 90 | 1 | 0.00 |
| | | 90 | 100 | 1 | 0.00 |
| | minimum width | 0.0 | 5.0 | 241 | 0.30 |
| | | 5.0 | 10.0 | 106 | 2.07 |
| | | 10.0 | 15.0 | 29 | 3.47 |
| | | 15.0 | 20.0 | 16 | 1.99 |
| | | 20.0 | 25.0 | 5 | 0.00 |
| | | 25.0 | 30.0 | 1 | 0.00 |
| | | 30.0 | 35.0 | 3 | 0.00 |
| | | 45.0 | 50.0 | 1 | 0.00 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | minimum width | 50.0 | 55.0 | 2 | 0.00 |
| | | 75.0 | 100.0 | 1 | 0.00 |
| | nitrates | 0 | 7.5 | 263 | 0.55 |
| | | 7.5 | 15.0 | 99 | 2.26 |
| | | 15.0 | 22.5 | 9 | 2.07 |
| | | 22.5 | 30.0 | 6 | 1.58 |
| | | 20.0 | 37.5 | 5 | 1.45 |
| | | 67.5 | 75.0 | 1 | 0.00 |
| | | 90.0 | 97.5 | 1 | 0.00 |
| | pH | 3.5 | 4.0 | 1 | 0.00 |
| | | 4.0 | 4.5 | 1 | 0.00 |
| | | 6.0 | 6.5 | 1 | 0.00 |
| | | 6.5 | 7.0 | 10 | 0.88 |
| | | 7.0 | 7.5 | 39 | 0.21 |
| | | 7.5 | 8.0 | 114 | 0.61 |
| | | 8.0 | 8.5 | 149 | 1.01 |
| | | 8.5 | 9.0 | 72 | 2.30 |
| | | 9.0 | 9.5 | 14 | 0.00 |
| | riffle | 0 | 15 | 302 | 0.82 |
| | | 15 | 30 | 62 | 2.09 |
| | | 30 | 45 | 26 | 3.25 |
| | | 45 | 60 | 5 | 0.00 |
| | | 75 | 90 | 3 | 0.00 |
| | | 90 | 100 | 1 | 0.00 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | turbidity | 0 | 30 | 161 | 1.77 |
| | | 30 | 60 | 49 | 1.54 |
| | | 60 | 90 | 18 | 0.61 |
| | | 90 | 120 | 10 | 0.01 |
| | | 120 | 150 | 4 | 0.00 |
| | | 150 | 180 | 2 | 0.00 |
| | | 210 | 240 | 1 | 0.00 |
| | | 270 | 300 | 2 | 0.00 |
| | | 360 | 390 | 1 | 0.00 |
| | | 390 | 420 | 1 | 0.00 |
| | | 450 | 480 | 2 | 0.00 |
| | | 510 | 540 | 1 | 0.00 |
| | | 540 | 570 | 1 | 0.00 |
| | water temperature | 12 | 16 | 27 | 0.02 |
| | | 16 | 20 | 45 | 0.45 |
| | | 20 | 24 | 98 | 1.10 |
| | | 24 | 28 | 129 | 2.15 |
| | | 28 | 32 | 41 | 0.89 |
| | | 32 | 36 | 3 | 0.00 |
| | | 36 | 40 | 1 | 0.00 |
| Slenderhead darter | calcium hardness | 0 | 100 | 2 | 0.50 |
| | | 100 | 200 | 7 | 0.25 |
| | | 200 | 300 | 3 | 2.65 |
| | | 300 | 400 | 3 | 0.70 |
| | | 400 | 500 | 2 | 0.56 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Slenderhead darter | calcium hardness | 500 | 600 | 1 | 0.11 |
| | | 600 | 700 | 2 | 0.22 |
| | | 1300 | 1400 | 1 | 0.11 |
| | chlorides | 0 | 50 | 15 | 0.87 |
| | | 50 | 100 | 6 | 0.33 |
| | | 100 | 150 | 1 | 0.33 |
| | | 150 | 200 | 2 | 0.16 |
| | | 200 | 250 | 1 | 0.78 |
| | conductivity | 0 | 300 | 1 | 0.11 |
| | | 300 | 600 | 8 | 0.36 |
| | | 600 | 900 | 8 | 0.61 |
| | | 900 | 1200 | 2 | 0.11 |
| | | 1200 | 1500 | 1 | 0.11 |
| | | 1500 | 1800 | 2 | 0.84 |
| | | 1800 | 2100 | 1 | 0.78 |
| | | 2700 | 3000 | 1 | 0.33 |
| | | 3900 | 4200 | 1 | 0.22 |
| | dissolved oxygen | 4 | 6 | 2 | 0.11 |
| | | 6 | 8 | 6 | 1.68 |
| | | 8 | 10 | 12 | 0.55 |
| | | 10 | 12 | 3 | 0.44 |
| | | 12 | 14 | 3 | 0.37 |
| | | 16 | 18 | 1 | 0.67 |
| | | 318 | 20 | 2 | 0.72 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Slenderhead darter | gradient | 0.0 | 0.5 | 10 | 0.51 |
| | | 0.5 | 1.0 | 11 | 0.58 |
| | | 1.0 | 1.5 | 5 | 2.15 |
| | | 1.5 | 2.0 | 2 | 0.33 |
| | | 3.0 | 3.5 | 1 | 0.11 |
| | growing season | 175 | 180 | 10 | 0.42 |
| | | 185 | 190 | 7 | 1.32 |
| | | 190 | 200 | 15 | 0.66 |
| | maximum stream width | 5 | 10 | 4 | 0.50 |
| | | 10 | 15 | 9 | 1.59 |
| | | 15 | 20 | 5 | 0.31 |
| | | 20 | 25 | 3 | 0.78 |
| | | 25 | 30 | 4 | 0.11 |
| | | 30 | 35 | 1 | 0.11 |
| | | 35 | 40 | 1 | 0.11 |
| | | 45 | 50 | 1 | 0.22 |
| | mean depth | 0.00 | 0.25 | 2 | 0.44 |
| | | 0.25 | 0.50 | 16 | 0.74 |
| | | 0.50 | 0.75 | 6 | 1.49 |
| | | 0.75 | 1.00 | 4 | 0.28 |
| | | 1.00 | 1.25 | 3 | 0.14 |
| | | 1.25 | 1.50 | 1 | 0.22 |
| | mean width | 0 | 5 | 1 | 0.22 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Slenderhead darter | mean width | 5 | 10 | 6 | 1.75 |
| | | 10 | 15 | 11 | 0.70 |
| | | 15 | 20 | 8 | 0.42 |
| | | 20 | 25 | 3 | 0.22 |
| | | 25 | 30 | 1 | 0.22 |
| | | 30 | 35 | 2 | 0.39 |
| | minimum stream width | 0 | 5 | 5 | 2.08 |
| | | 5 | 10 | 10 | 0.44 |
| | | 10 | 15 | 9 | 0.63 |
| | | 15 | 20 | 4 | 0.14 |
| | nitrates | 0.0 | 3.0 | 2 | 0.16 |
| | | 3.0 | 6.0 | 5 | 0.40 |
| | | 6.0 | 9.0 | 15 | 0.87 |
| | | 9.0 | 12.0 | 3 | 0.37 |
| | pH | 6.5 | 7.0 | 2 | 0.84 |
| | | 7.0 | 7.5 | 2 | 0.16 |
| | | 7.5 | 8.0 | 2 | 0.67 |
| | | 8.0 | 8.5 | 12 | 0.26 |
| | | 8.5 | 9.0 | 7 | 1.44 |
| | pool | 0 | 20 | 8 | 1.26 |
| | | 20 | 40 | 1 | 0.44 |
| | | 40 | 60 | 4 | 0.75 |
| | | 60 | 80 | 4 | 0.36 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Slenderhead darter | pool | 80 | 100 | 9 | 0.23 |
| | | 100 | 100 | 4 | 0.70 |
| | riffle | 0 | 10 | 14 | 1.08 |
| | | 10 | 20 | 8 | 0.32 |
| | | 20 | 30 | 2 | 0.33 |
| | | 30 | 40 | 5 | 0.35 |
| | | 40 | 50 | 2 | 1.34 |
| | run | 0 | 20 | 18 | 0.48 |
| | | 20 | 40 | 4 | 0.28 |
| | | 60 | 80 | 2 | 0.39 |
| | | 80 | 100 | 2 | 0.33 |
| | | 100 | 100 | 4 | 2.15 |
| | runoff | 0.0 | 1.5 | 6 | 0.97 |
| | | 1.5 | 3.0 | 9 | 1.38 |
| | | 3.0 | 4.5 | 8 | 0.14 |
| | | 6.0 | 7.5 | 1 | 0.22 |
| | | 7.5 | 9.0 | 4 | 0.19 |
| | | 9.0 | 10.5 | 4 | 0.78 |
| | sulfates | 0 | 200 | 13 | 0.91 |
| | | 200 | 400 | 7 | 0.44 |
| | | 400 | 600 | 2 | 0.16 |
| | | 800 | 1000 | 2 | 0.50 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Slenderhead darter | total alkalinity | 50 | 100 | 3 | 0.78 |
| | | 100 | 150 | 3 | 0.33 |
| | | 150 | 200 | 7 | 0.19 |
| | | 200 | 250 | 8 | 1.24 |
| | | 250 | 300 | 3 | 0.14 |
| | | 550 | 600 | 1 | 1.45 |
| | total dissolved solids | 0 | 200 | 8 | 0.36 |
| | | 200 | 400 | 8 | 0.61 |
| | | 400 | 600 | 3 | 0.11 |
| | | 600 | 800 | 3 | 0.82 |
| | | 1200 | 400 | 1 | 0.33 |
| | | 1600 | 1800 | 1 | 0.22 |
| | total phosphates | 0.0 | 0.3 | 17 | 0.31 |
| | | 0.3 | 0.6 | 7 | 0.35 |
| | | 0.9 | 1.2 | 1 | 7.73 |
| | | 1.2 | 1.5 | 2 | 0.61 |
| | | 3.3 | 3.6 | 1 | 0.78 |
| | turbidity | 0 | 25 | 10 | 0.42 |
| | | 25 | 50 | 5 | 0.53 |
| | | 50 | 75 | 1 | 0.11 |
| | | 100 | 125 | 1 | 0.11 |
| | volume of flow | 0.0 | 0.5 | 14 | 0.86 |
| | | 0.5 | 1.0 | 6 | 1.00 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing Crop |
|---|---|---|---|---|---|
| Slenderhead darter | volume of flow | 1.0 | 1.5 | 2 | 0.44 |
| | | 1.5 | 2.0 | 1 | 0.11 |
| | | 2.0 | 2.5 | 1 | 0.11 |
| | | 4.0 | 4.5 | 1 | 0.56 |
| | | 6.5 | 7.0 | 1 | 0.67 |
| | water temperature | 12 | 16 | 1 | 2.91 |
| | | 16 | 20 | 3 | 0.63 |
| | | 20 | 24 | 5 | 1.88 |
| | | 24 | 28 | 20 | 0.38 |
| | | 28 | 32 | 2 | 0.28 |
| Orangethroat darter | calcium | 0 | 100 | 8 | 0.15 |
| | | 100 | 200 | 48 | 3.18 |
| | | 200 | 300 | 41 | 1.84 |
| | | 300 | 400 | 16 | 6.33 |
| | | 400 | 500 | 5 | 0.13 |
| | | 500 | 600 | 2 | 3.08 |
| | | 600 | 700 | 4 | 0.39 |
| | | 700 | 800 | 2 | 0.39 |
| | | 900 | 1000 | 2 | 0.84 |
| | | 1300 | 1400 | 1 | 0.22 |
| | conductivity | 0 | 200 | 2 | 0.22 |
| | | 200 | 400 | 12 | 1.92 |
| | | 400 | 600 | 26 | 3.45 |
| | | 600 | 800 | 17 | 0.71 |
| | | 800 | 1000 | 5 | 0.94 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Orangethroat darter | conductivity | 1000 | 1200 | 5 | 0.53 |
| | | 1200 | 1400 | 1 | 0.11 |
| | | 1400 | 1600 | 2 | 0.11 |
| | | 1600 | 1800 | 2 | 0.16 |
| | | 1800 | 2000 | 1 | 0.11 |
| | | 2200 | 2400 | 1 | 6.05 |
| | | 2600 | 2800 | 1 | 0.11 |
| | | 4000 | 4200 | 2 | 0.33 |
| | dissolved oxygen | 3 | 6 | 9 | 0.17 |
| | | 6 | 9 | 51 | 2.49 |
| | | 9 | 12 | 41 | 2.02 |
| | | 12 | 15 | 25 | 1.41 |
| | | 15 | 18 | 9 | 5.39 |
| | | 18 | 20 | 4 | 0.61 |
| | gradient | 0.00 | 0.75 | 27 | 1.57 |
| | | 0.75 | 1.50 | 44 | 1.29 |
| | | 1.50 | 2.25 | 24 | 4.24 |
| | | 2.25 | 3.00 | 15 | 0.62 |
| | | 3.00 | 3.75 | 12 | 1.97 |
| | | 3.75 | 4.50 | 8 | 2.28 |
| | | 4.50 | 5.23 | 4 | 8.77 |
| | growing season (frost-free days) | 80 | 90 | 1 | 0.67 |
| | | 160 | 170 | 22 | 2.63 |
| | | 170 | 180 | 36 | 2.70 |
| | | 180 | 190 | 61 | 2.37 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Orangethroat darter | growing season (frost-free days) | 190 | 200 | 30 | 1.77 |
| | magnesium hardness | 0 | 50 | 57 | 3.00 |
| | | 50 | 100 | 33 | 3.52 |
| | | 100 | 150 | 17 | 2.51 |
| | | 200 | 250 | 8 | 0.33 |
| | | 250 | 300 | 2 | 0.16 |
| | | 350 | 400 | 1 | 0.11 |
| | | 400 | 450 | 1 | 6.05 |
| | | 450 | 500 | 1 | 0.33 |
| | | 500 | 550 | 1 | 0.56 |
| | maximum stream width | 0 | 5 | 27 | 5.03 |
| | | 5 | 10 | 44 | 3.32 |
| | | 10 | 15 | 33 | 0.55 |
| | | 15 | 20 | 22 | 0.78 |
| | | 20 | 25 | 7 | 4.78 |
| | | 25 | 30 | 5 | 0.12 |
| | | 30 | 35 | 2 | 0.11 |
| | | 35 | 40 | 2 | 0.11 |
| | | 45 | 50 | 1 | 0.11 |
| | mean depth | 0.0 | 0.5 | 91 | 1.97 |
| | | 0.5 | 1.0 | 45 | 2.06 |
| | | 1.0 | 1.5 | 11 | 6.89 |
| | | 1.5 | 2.0 | 3 | 1.86 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Orangethroat darter | mean width | 0 | 5 | 44 | 4.18 |
| | | 5 | 10 | 59 | 2.08 |
| | | 10 | 15 | 26 | 0.41 |
| | | 15 | 20 | 13 | 2.67 |
| | | 20 | 25 | 3 | 0.11 |
| | | 25 | 30 | 2 | 0.11 |
| | | 30 | 35 | 1 | 0.11 |
| | minimum stream width | 0 | 5 | 8 | 3.72 |
| | | 5 | 10 | 43 | 0.68 |
| | | 10 | 15 | 10 | 0.25 |
| | | 15 | 20 | 4 | 0.11 |
| | | 20 | 25 | 1 | 0.11 |
| | nitrates | 0 | 5 | 27 | 0.87 |
| | | 5 | 10 | 89 | 3.10 |
| | | 10 | 15 | 11 | 1.70 |
| | | 15 | 20 | 3 | 2.27 |
| | | 20 | 25 | 2 | 9.86 |
| | | 25 | 30 | 2 | 2.07 |
| | | 35 | 40 | 2 | 0.11 |
| | | 65 | 70 | 1 | 0.33 |
| | | 90 | -- | 1 | 0.33 |
| | pH | 6.0 | 6.5 | 1 | 6.05 |
| | | 6.5 | 7.0 | 4 | 0.16 |
| | | 7.0 | 7.5 | 15 | 1.70 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Orangethroat darter | pool | 0 | 15 | 41 | 1.29 |
| | | 15 | 30 | 8 | 3.08 |
| | | 30 | 45 | 22 | 2.66 |
| | | 45 | 60 | 18 | 2.56 |
| | | 60 | 75 | 10 | 7.64 |
| | | 75 | 90 | 16 | 1.75 |
| | | 90 | 100 | 34 | 1.96 |
| | riffle | 0 | 15 | 99 | 1.91 |
| | | 15 | 30 | 31 | 4.33 |
| | | 30 | 45 | 11 | 1.00 |
| | | 45 | 60 | 5 | 1.45 |
| | | 60 | 75 | 2 | 5.43 |
| | | 75 | 90 | 1 | 0.22 |
| | run | 0 | 15 | 60 | 3.23 |
| | | 15 | 30 | 10 | 0.49 |
| | | 30 | 45 | 20 | 1.32 |
| | | 45 | 60 | 12 | 4.52 |
| | | 60 | 75 | 8 | 1.24 |
| | | 75 | 90 | 7 | 1.90 |
| | | 90 | 100 | 31 | 1.59 |
| | runoff | 0 | 1 | 19 | 3.03 |
| | | 1 | 2 | 19 | 1.40 |
| | | 2 | 3 | 48 | 2.38 |
| | | 5 | 6 | 43 | 3.18 |
| | | 6 | 7 | 10 | 1.01 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Orangethroat darter | runoff | 8 | 9 | 8 | 0.93 |
| | | 10 | 11 | 3 | 0.18 |
| | sulfates | 0 | 75 | 82 | 2.82 |
| | | 75 | 150 | 11 | 2.80 |
| | | 150 | 225 | 14 | 2.01 |
| | | 225 | 300 | 15 | 1.49 |
| | | 300 | 375 | 3 | 0.26 |
| | | 375 | 450 | 2 | 0.22 |
| | | 450 | 525 | 2 | 0.16 |
| | | 675 | 750 | 1 | 0.22 |
| | | 825 | 900 | 1 | 0.11 |
| | | 900 | 975 | 1 | 0.22 |
| | total alkalinity | 50 | 100 | 5 | 1.86 |
| | | 100 | 150 | 14 | 1.85 |
| | | 150 | 200 | 25 | 2.91 |
| | | 200 | 250 | 52 | 3.44 |
| | | 250 | 300 | 37 | 1.14 |
| | | 300 | 350 | 5 | 2.80 |
| | | 350 | 400 | 3 | 2.24 |
| | | 550 | 600 | 1 | 0.11 |
| | total phosphates | 0.0 | 0.75 | 116 | 2.08 |
| | | 0.75 | 1.50 | 14 | 1.81 |
| | | 1.50 | 2.25 | 6 | 13.46 |
| | | 2.25 | 3.00 | 1 | 0.11 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Orangethroat darter | total phosphates | 3.75 | 4.50 | 1 | 0.78 |
| | | 4.50 | 5.25 | 1 | 0.11 |
| | turbidity | 0 | 25 | 76 | 3.39 |
| | | 25 | 50 | 23 | 2.12 |
| | | 50 | 75 | 8 | 1.35 |
| | | 75 | 100 | 2 | 0.39 |
| | | 100 | 125 | 2 | 0.16 |
| | | 275 | 300 | 1 | 0.22 |
| | | 500 | 525 | 1 | 0.22 |
| | velocity | 0.0 | 0.5 | 128 | 2.33 |
| | | 0.5 | 1.0 | 3 | 6.12 |
| | | 1.0 | 1.5 | 2 | 0.11 |
| | | 5.5 | 5.0 | 1 | 0.22 |
| | volume of flow | 0 | 2 | 128 | 2.47 |
| | | 2 | 4 | 2 | 0.11 |
| | | 4 | 4 | 2 | 0.28 |
| | | 6 | 8 | 1 | 0.11 |
| | | 24 | 26 | 1 | 0.22 |
| | water temperature | 5 | 10 | 8 | 1.98 |
| | | 10 | 15 | 15 | 3.30 |
| | | 20 | 25 | 55 | 2.53 |
| | | 25 | 30 | 55 | 2.27 |
| | | 30 | 35 | 3 | 0.63 |
| | | 35 | 40 | 1 | 0.11 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | chlorides | 0 | 100 | 154 | 11.47 |
| | | 100 | 200 | 23 | 5.23 |
| | | 200 | 300 | 2 | 1.12 |
| | | 300 | 400 | 7 | 26.61 |
| | | 400 | 500 | 2 | 18.49 |
| | | 500 | 600 | 1 | 0.78 |
| | | 600 | 700 | 2 | 24.99 |
| | | 1200 | 1300 | 1 | 0.67 |
| | conductivity | 0 | 200 | 2 | 0.72 |
| | | 200 | 400 | 17 | 4.37 |
| | | 400 | 600 | 29 | 8.68 |
| | | 600 | 800 | 27 | 12.65 |
| | | 800 | 1000 | 12 | 19.01 |
| | | 1000 | 1200 | 8 | 17.19 |
| | | 1200 | 1400 | 3 | 0.56 |
| | | 1400 | 1600 | 2 | 2.18 |
| | | 1600 | 1800 | 2 | 0.84 |
| | | 1800 | 2000 | 1 | 0.67 |
| | | 2000 | 2200 | 3 | 12.74 |
| | | 2200 | 2400 | 1 | 4.70 |
| | | 2400 | 2600 | 1 | 12.88 |
| | | 2600 | 2800 | 1 | 2.46 |
| | | 3000 | 3200 | 2 | 8.18 |
| | | 4000 | 4200 | 1 | 1.90 |
| | | 9000 | 9200 | 1 | 0.78 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | dissolved oxygen | 4 | 6 | 8 | 2.59 |
| | | 6 | 8 | 35 | 6.68 |
| | | 10 | 12 | 46 | 13.87 |
| | | 12 | 14 | 27 | 17.58 |
| | | 14 | 16 | 13 | 16.92 |
| | | 16 | 18 | 8 | 16.99 |
| | | 19 | 20 | 6 | 21.07 |
| | gradient | 0.00 | 0.75 | 34 | 3.81 |
| | | 0.75 | 1.50 | 73 | 7.20 |
| | | 1.50 | 2.25 | 34 | 25.84 |
| | | 2.25 | 3.00 | 15 | 2.78 |
| | | 3.00 | 3.75 | 13 | 11.69 |
| | | 3.75 | 4.50 | 8 | 6.69 |
| | | 4.50 | 5.25 | 5 | 26.76 |
| | | 7.50 | 8.25 | 1 | 40.46 |
| | magnesium hardness | 0 | 50 | 75 | 9.60 |
| | | 50 | 100 | 47 | 15.72 |
| | | 100 | 150 | 31 | 11.09 |
| | | 150 | 200 | 7 | 11.57 |
| | | 200 | 250 | 9 | 9.85 |
| | | 250 | 300 | 2 | 11.04 |
| | | 350 | 400 | 1 | 0.11 |
| | | 400 | 450 | 1 | 4.70 |
| | | 450 | 500 | 2 | 5.54 |
| | | 500 | 550 | 2 | 1.84 |
| | | 550 | 600 | 1 | 0.78 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | magnesium hardness | 700 | 750 | 1 | 94.26 |
| | maximum stream width | 0 | 5 | 44 | 27.82 |
| | | 5 | 10 | 64 | 10.83 |
| | | 10 | 15 | 45 | 4.15 |
| | | 15 | 20 | 23 | 2.71 |
| | | 20 | 25 | 10 | 1.28 |
| | | 25 | 30 | 4 | 0.25 |
| | | 30 | 35 | 3 | 0.14 |
| | | 35 | 40 | 2 | 2.63 |
| | | 40 | 45 | 1 | 0.11 |
| | mean depth | 0.0 | 0.2 | 49 | 13.86 |
| | | 0.2 | 0.4 | 67 | 14.12 |
| | | 0.4 | 0.6 | 31 | 7.67 |
| | | 0.6 | 0.8 | 33 | 6.29 |
| | | 0.8 | 1.0 | 11 | 6.60 |
| | | 1.0 | 1.2 | 7 | 8.45 |
| | | 1.2 | 1.4 | 4 | 3.25 |
| | | 1.4 | 1.6 | 2 | 0.11 |
| | | 3.0 | 3.2 | 1 | 4.14 |
| | mean width | 0 | 2 | 8 | 46.86 |
| | | 2 | 4 | 48 | 20.14 |
| | | 4 | 6 | 32 | 9.05 |
| | | 6 | 8 | 40 | 11.95 |
| | | 8 | 10 | 22 | 2.87 |
| | | 10 | 12 | 9 | 0.67 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | mean width | 12 | 14 | 16 | 0.52 |
| | | 14 | 16 | 11 | 1.44 |
| | | 16 | 18 | 5 | 1.99 |
| | | 18 | 20 | 4 | 0.28 |
| | | 20 | 22 | 3 | 0.11 |
| | | 22 | 24 | 1 | 0.11 |
| | | 28 | 30 | 1 | 0.11 |
| | | 30 | 32 | 2 | 2.63 |
| | | 32 | 34 | 1 | 0.11 |
| | | 38 | 40 | 1 | 0.11 |
| | | 44 | 46 | 1 | 0.11 |
| | minimum stream width | 0 | 2 | 37 | 26.24 |
| | | 2 | 4 | 62 | 12.06 |
| | | 4 | 6 | 37 | 5.75 |
| | | 6 | 8 | 30 | 7.93 |
| | | 8 | 10 | 12 | 0.56 |
| | | 10 | 12 | 5 | 0.94 |
| | | 12 | 14 | 5 | 1.97 |
| | | 14 | 16 | 6 | 0.37 |
| | | 16 | 18 | 1 | 0.11 |
| | | 18 | 20 | 2 | 0.11 |
| | | 26 | 28 | 1 | 5.15 |
| | nitrates | 0 | 5 | 34 | 14.09 |
| | | 5 | 10 | 122 | 10.41 |
| | | 10 | 15 | 15 | 17.97 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | nitrates | 15 | 20 | 3 | 19.05 |
| | | 20 | 25 | 3 | 11.61 |
| | | 25 | 30 | 3 | 1.45 |
| | | 30 | 35 | 1 | 6.72 |
| | | 35 | 40 | 3 | 11.69 |
| | | 65 | 70 | 1 | 0.22 |
| | | 90 | 95 | 1 | 1.34 |
| | pH | 6.0 | 6.5 | 1 | 4.70 |
| | | 6.5 | 7.0 | 4 | 1.00 |
| | | 7.0 | 7.5 | 22 | 9.59 |
| | | 7.5 | 8.0 | 53 | 21.16 |
| | | 8.0 | 8.5 | 65 | 8.13 |
| | | 8.5 | 9.0 | 40 | 6.32 |
| | | 9.0 | 9.5 | 6 | 2.70 |
| | pool | 0 | 15 | 67 | 11.88 |
| | | 15 | 30 | 16 | 12.93 |
| | | 30 | 45 | 26 | 11.85 |
| | | 45 | 60 | 19 | 10.86 |
| | | 60 | 75 | 16 | 8.79 |
| | | 75 | 90 | 19 | 7.02 |
| | | 90 | 100 | 40 | 10.68 |
| | riffle | 0 | 10 | 123 | 10.51 |
| | | 10 | 20 | 37 | 8.40 |
| | | 20 | 30 | 22 | 18.68 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | riffle | 30 | 40 | 10 | 11.72 |
| | | 40 | 50 | 7 | 8.58 |
| | | 50 | 60 | 2 | 4.31 |
| | | 60 | 70 | 2 | 6.16 |
| | | 70 | 80 | 1 | 5.15 |
| | run | 0 | 15 | 73 | 9.91 |
| | | 15 | 30 | 11 | 3.19 |
| | | 30 | 45 | 26 | 12.24 |
| | | 45 | 60 | 14 | 24.97 |
| | | 60 | 75 | 11 | 16.94 |
| | | 75 | 90 | 14 | 5.13 |
| | | 90 | 100 | 54 | 7.89 |
| | sulfates | 0 | 50 | 72 | 10.34 |
| | | 50 | 100 | 29 | 9.94 |
| | | 100 | 150 | 14 | 15.92 |
| | | 150 | 200 | 14 | 15.01 |
| | | 200 | 250 | 26 | 18.08 |
| | | 250 | 300 | 10 | 1.78 |
| | | 300 | 350 | 4 | 5.80 |
| | | 350 | 400 | 3 | 2.16 |
| | | 400 | 450 | 2 | 2.24 |
| | | 500 | 550 | 1 | 0.22 |
| | | 700 | 750 | 1 | 34.52 |
| | | 750 | 800 | 2 | 0.56 |
| | | 800 | 850 | 1 | 0.11 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | sulfates | 900 | 950 | 1 | 9.19 |
| | | 950 | 1000 | 1 | 94.26 |
| | | 1250 | 1300 | 1 | 0.11 |
| | total alkalinity | 50 | 100 | 9 | 29.33 |
| | | 100 | 150 | 21 | 3.26 |
| | | 150 | 200 | 34 | 12.55 |
| | | 200 | 250 | 66 | 10.26 |
| | | 250 | 300 | 45 | 10.64 |
| | | 300 | 350 | 11 | 18.17 |
| | | 350 | 400 | 6 | 10.06 |
| | | 400 | 450 | 2 | 0.44 |
| | | 550 | 600 | 1 | 1.45 |
| | total dissolved solids | 0 | 200 | 34 | 5.14 |
| | | 200 | 400 | 41 | 15.99 |
| | | 400 | 600 | 15 | 12.31 |
| | | 600 | 800 | 5 | 1.97 |
| | | 800 | 1000 | 5 | 9.21 |
| | | 1000 | 1200 | 2 | 8.79 |
| | | 1200 | 1400 | 2 | 5.82 |
| | | 1600 | 1800 | 1 | 1.90 |
| | | 4200 | 4400 | 1 | 0.78 |
| | total phosphates | 0.0 | 0.5 | 130 | 9.34 |
| | | 0.5 | 1.0 | 33 | 19.48 |
| | | 1.0 | 1.5 | 12 | 19.94 |
| | | 1.5 | 2.0 | 5 | 3.54 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | total phosphates | 2.0 | 2.5 | 3 | 4.93 |
| | | 2.5 | 3.0 | 2 | 1.73 |
| | | 3.0 | 3.5 | 1 | 0.11 |
| | | 3.5 | 4.0 | 1 | 8.40 |
| | | 4.0 | 4.5 | 1 | 27.01 |
| | | 4.5 | 5.0 | 1 | 2.01 |
| | turbidity | 0 | 25 | 84 | 11.26 |
| | | 25 | 50 | 32 | 6.58 |
| | | 50 | 75 | 11 | 7.21 |
| | | 75 | 100 | 2 | 1.40 |
| | | 100 | 125 | 4 | 2.40 |
| | | 125 | 150 | 1 | 0.22 |
| | | 150 | 175 | 1 | 8.40 |
| | | 500 | 550 | 1 | 1.90 |
| | velocity | 0.0 | 0.2 | 135 | 12.25 |
| | | 0.2 | 0.4 | 34 | 10.35 |
| | | 0.4 | 0.6 | 8 | 16.22 |
| | | 0.6 | 0.8 | 3 | 1.34 |
| | | 0.8 | 1.0 | 3 | 7.24 |
| | | 1.0 | 1.2 | 2 | 0.22 |
| | | 1.4 | 1.6 | 1 | 0.44 |
| | | 5.6 | 5.8 | 1 | 0.67 |
| | volume of flow | 0.0 | 0.5 | 151 | 13.90 |
| | | 0.5 | 1.0 | 15 | 3.05 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | volume of flow | 1.0 | 1.5 | 4 | 1.68 |
| | | 1.5 | 2.0 | 6 | 0.76 |
| | | 2.0 | 2.5 | 2 | 0.11 |
| | | 2.5 | 3.0 | 3 | 1.83 |
| | | 4.0 | 4.5 | 3 | 0.37 |
| | | 6.0 | 6.5 | 1 | 0.11 |
| | | 6.5 | 7.0 | 1 | 0.11 |
| | | 25.0 | 25.5 | 1 | 0.67 |
| | water temperature | 0 | 4 | 1 | 0.22 |
| | | 4 | 8 | 6 | 3.62 |
| | | 8 | 12 | 21 | 12.50 |
| | | 12 | 16 | 11 | 27.14 |
| | | 16 | 20 | 21 | 23.12 |
| | | 20 | 24 | 47 | 9.44 |
| | | 24 | 28 | 65 | 8.70 |
| | | 28 | 32 | 24 | 2.54 |
| | | 32 | 36 | 2 | 5.71 |
| | | 36 | 40 | 1 | 0.33 |
| Channel catfish | conductivity | 0 | 500 | 63 | 18.28 |
| | | 500 | 1000 | 78 | 19.91 |
| | | 1000 | 1500 | 36 | 38.50 |
| | | 1500 | 2000 | 13 | 64.49 |
| | | 2000 | 2500 | 10 | 23.70 |
| | | 2500 | 3000 | 6 | 23.44 |
| | | 3000 | 3500 | 6 | 49.52 |
| | | 3500 | 4000 | 3 | 7.21 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | conductivity | 6000 | 6500 | 1 | 32.39 |
| | dissolved oxygen | 2 | 4 | 2 | 7.39 |
| | | 4 | 6 | 21 | 3.58 |
| | | 6 | 8 | 72 | 23.50 |
| | | 8 | 10 | 86 | 25.06 |
| | | 10 | 12 | 86 | 25.99 |
| | | 12 | 14 | 56 | 37.00 |
| | | 14 | 16 | 28 | 9.93 |
| | | 16 | 18 | 17 | 14.05 |
| | | 18 | 20 | 11 | 14.70 |
| | gradient | 0 | 1 | 152 | 31.73 |
| | | 1 | 2 | 129 | 21.71 |
| | | 2 | 3 | 49 | 25.81 |
| | | 3 | 4 | 26 | 30.92 |
| | | 4 | 5 | 6 | 1.38 |
| | | 5 | 6 | 6 | 13.95 |
| | maximum stream width | 0 | 3 | 21 | 15.48 |
| | | 3 | 6 | 89 | 15.46 |
| | | 6 | 9 | 88 | 25.00 |
| | | 9 | 12 | 61 | 28.85 |
| | | 12 | 15 | 48 | 33.70 |
| | | 15 | 18 | 34 | 39.94 |
| | | 18 | 21 | 15 | 67.67 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | maximum stream width | 21 | 24 | 12 | 4.25 |
| | | 24 | 27 | 7 | 17.38 |
| | | 27 | 30 | 4 | 11.20 |
| | | 30 | 33 | 7 | 8.85 |
| | | 33 | 36 | 2 | 0.95 |
| | | 36 | 39 | 7 | 6.00 |
| | | 39 | 42 | 1 | 2.80 |
| | | 45 | 48 | 2 | 11.20 |
| | | 90 | 93 | 2 | 0.28 |
| | | 123 | 126 | 1 | 0.11 |
| | mean depth | 0.0 | 0.5 | 254 | 17.63 |
| | | 0.5 | 1.0 | 135 | 28.57 |
| | | 1.0 | 1.5 | 23 | 92.32 |
| | | 1.5 | 2.0 | 5 | 36.09 |
| | | 2.0 | 2.5 | 1 | 0.33 |
| | mean width | 0 | 3 | 46 | 20.64 |
| | | 3 | 6 | 132 | 13.55 |
| | | 6 | 9 | 94 | 31.68 |
| | | 9 | 12 | 51 | 36.52 |
| | | 12 | 15 | 36 | 33.64 |
| | | 15 | 18 | 22 | 73.86 |
| | | 18 | 21 | 9 | 8.59 |
| | | 21 | 24 | 8 | 10.39 |
| | | 24 | 27 | 3 | 4.03 |
| | | 27 | 30 | 2 | 1.28 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | mean width | 30 | 33 | 6 | 6.91 |
| | | 33 | 36 | 2 | 3.75 |
| | | 45 | 48 | 2 | 0.33 |
| | | 72 | 75 | 1 | 0.11 |
| | | 81 | 84 | 1 | 0.56 |
| | | 108 | 111 | 1 | 0.11 |
| | minimum stream width | 0 | 3 | 112 | 16.59 |
| | | 3 | 6 | 152 | 24.08 |
| | | 6 | 9 | 68 | 32.77 |
| | | 9 | 12 | 26 | 23.28 |
| | | 12 | 15 | 18 | 75.79 |
| | | 15 | 18 | 10 | 21.71 |
| | | 18 | 21 | 6 | 1.94 |
| | | 21 | 24 | 4 | 4.51 |
| | | 27 | 30 | 1 | 19.81 |
| | | 30 | 33 | 3 | 2.54 |
| | | 75 | 78 | 1 | 0.56 |
| | | 99 | 102 | 1 | 0.11 |
| | nitrates | 0 | 5 | 91 | 17.16 |
| | | 5 | 10 | 248 | 23.36 |
| | | 10 | 15 | 23 | 58.13 |
| | | 15 | 20 | 7 | 53.17 |
| | | 20 | 25 | 5 | 13.31 |
| | | 25 | 30 | 3 | 12.10 |
| | | 35 | 40 | 3 | 1.75 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | pH | 6.0 | 6.5 | 1 | 0.11 |
| | | 6.5 | 7.0 | 10 | 3.25 |
| | | 7.0 | 7.5 | 39 | 12.74 |
| | | 7.5 | 8.0 | 114 | 19.29 |
| | | 8.0 | 8.5 | 149 | 31.63 |
| | | 8.5 | 9.0 | 72 | 27.08 |
| | | 9.0 | 9.5 | 14 | 43.03 |
| | pool | 0 | 15 | 158 | 18.15 |
| | | 15 | 30 | 25 | 18.77 |
| | | 30 | 45 | 41 | 40.58 |
| | | 45 | 60 | 34 | 49.83 |
| | | 60 | 75 | 25 | 28.83 |
| | | 75 | 90 | 33 | 34.44 |
| | | 90 | 100 | 93 | 18.66 |
| | riffle | 0 | 15 | 302 | 23.02 |
| | | 15 | 30 | 62 | 34.17 |
| | | 30 | 45 | 26 | 18.32 |
| | | 45 | 60 | 7 | 62.49 |
| | | 60 | 75 | 5 | 2.64 |
| | | 75 | 90 | 3 | 12.55 |
| | | 90 | 100 | 1 | 1.34 |
| | run | 0 | 20 | 151 | 25.39 |
| | | 20 | 40 | 44 | 27.20 |
| | | 40 | 60 | 38 | 27.03 |
| | | 60 | 80 | 28 | 56.13 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | run | 80 | 100 | 25 | 25.34 |
| | | 100 | 100 | 122 | 15.01 |
| | runoff | 0 | 2 | 208 | 22.03 |
| | | 2 | 4 | 112 | 32.06 |
| | | 4 | 6 | 72 | 26.96 |
| | | 6 | 8 | 12 | 16.93 |
| | | 8 | 10 | 10 | 18.98 |
| | | 10 | 12 | 6 | 2.39 |
| | sulfates | 0 | 75 | 169 | 16.78 |
| | | 75 | 150 | 52 | 16.84 |
| | | 150 | 225 | 71 | 28.43 |
| | | 225 | 300 | 51 | 19.13 |
| | | 300 | 375 | 15 | 23.00 |
| | | 375 | 450 | 9 | 26.05 |
| | | 450 | 600 | 2 | 185.55 |
| | | 675 | 750 | 2 | 33.00 |
| | | 750 | 825 | 3 | 0.33 |
| | | 825 | 900 | 2 | 5.44 |
| | | 900 | 975 | 2 | 0.05 |
| | total alkalinity | 0 | 50 | 4 | 4.87 |
| | | 50 | 100 | 11 | 4.62 |
| | | 100 | 150 | 45 | 7.09 |
| | | 150 | 200 | 83 | 15.52 |
| | | 200 | 250 | 124 | 36.54 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | total alkalinity | 250 | 300 | 87 | 28.57 |
| | | 300 | 350 | 30 | 15.48 |
| | | 350 | 400 | 10 | 8.07 |
| | | 400 | 450 | 7 | 55.00 |
| | | 450 | 500 | 1 | 0.11 |
| | | 550 | 600 | 1 | 114.88 |
| | total dissolved solids | 0 | 200 | 56 | 15.39 |
| | | 200 | 400 | 69 | 17.54 |
| | | 400 | 600 | 38 | 39.88 |
| | | 600 | 800 | 11 | 75.00 |
| | | 1000 | 1200 | 5 | 11.79 |
| | | 1200 | 1400 | 8 | 18.69 |
| | | 1400 | 1600 | 1 | 1.45 |
| | | 1600 | 1800 | 4 | 6.33 |
| | | 1800 | 2000 | 2 | 81.37 |
| | | 3400 | 3600 | 1 | 32.39 |
| | turbidity | 0 | 30 | 161 | 31.42 |
| | | 30 | 60 | 49 | 22.60 |
| | | 60 | 90 | 18 | 6.76 |
| | | 90 | 120 | 10 | 9.07 |
| | | 120 | 150 | 4 | 0.50 |
| | | 270 | 300 | 2 | 3.92 |
| | | 510 | 540 | 1 | 3.02 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | volume of flow | 0 | 2 | 349 | 25.11 |
| | | 2 | 4 | 8 | 51.22 |
| | | 4 | 6 | 7 | 56.42 |
| | | 6 | 8 | 6 | 45.80 |
| | | 8 | 10 | 1 | 7.50 |
| | | 12 | 14 | 1 | 12.10 |
| | | 18 | 20 | 1 | 0.11 |
| | | 28 | 30 | 3 | 3.02 |
| | water temperature | 0 | 5 | 3 | 1.94 |
| | | 5 | 10 | 34 | 14.05 |
| | | 10 | 15 | 45 | 15.58 |
| | | 15 | 20 | 50 | 4.65 |
| | | 20 | 25 | 142 | 28.99 |
| | | 25 | 30 | 118 | 32.65 |
| | | 30 | 35 | 11 | 26.68 |
| | | 35 | 40 | 1 | 81.48 |
| Largemouth bass | chlorides | 0 | 40 | 205 | 6.37 |
| | | 40 | 80 | 74 | 1.89 |
| | | 80 | 120 | 36 | 1.06 |
| | | 120 | 160 | 20 | 1.09 |
| | | 160 | 200 | 7 | 14.71 |
| | | 200 | 240 | 9 | 13.76 |
| | | 240 | 280 | 5 | 4.77 |
| | | 320 | 360 | 4 | 0.02 |
| | | 360 | 400 | 4 | 0.11 |
| | | 400 | 440 | 8 | 0.01 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | chlorides | 840 | 880 | 1 | 2.24 |
| | | 960 | 1000 | 1 | 9.97 |
| | | 1840 | 1880 | 1 | 23.20 |
| | conductivity | 0 | 300 | 10 | 5.66 |
| | | 300 | 600 | 71 | 2.51 |
| | | 600 | 900 | 48 | 3.78 |
| | | 900 | 1200 | 35 | 1.29 |
| | | 1200 | 1500 | 13 | 0.06 |
| | | 1500 | 1800 | 5 | 4.77 |
| | | 1800 | 2100 | 3 | 0.01 |
| | | 2100 | 2400 | 3 | 0.28 |
| | | 2400 | 2700 | 3 | 0.11 |
| | | 2700 | 3000 | 5 | 0.42 |
| | | 3300 | 3600 | 2 | 4.98 |
| | | 3900 | 4200 | 3 | 13.37 |
| | | 6300 | 6600 | 1 | 23.20 |
| | dissolved oxygen | 4 | 6 | 21 | 2.61 |
| | | 6 | 8 | 72 | 6.52 |
| | | 8 | 10 | 86 | 4.96 |
| | | 10 | 12 | 86 | 2.07 |
| | | 12 | 14 | 56 | 2.65 |
| | | 14 | 16 | 28 | 2.33 |
| | | 16 | 18 | 17 | 2.86 |
| | | 18 | 20 | 11 | 15.81 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | gradient | 0.0 | 0.5 | 54 | 0.62 |
| | | 0.5 | 1.0 | 98 | 2.52 |
| | | 1.0 | 1.5 | 88 | 3.60 |
| | | 1.5 | 2.0 | 41 | 2.98 |
| | | 2.0 | 2.5 | 27 | 4.80 |
| | | 2.5 | 3.0 | 22 | 14.20 |
| | | 3.0 | 3.5 | 15 | 5.82 |
| | | 3.5 | 4.0 | 11 | 8.01 |
| | | 4.0 | 4.5 | 4 | 0.84 |
| | | 4.5 | 5.0 | 2 | 17.37 |
| | | 5.0 | 5.5 | 6 | 1.30 |
| | | 7.5 | 8.0 | 1 | 3.69 |
| | growing season | 160 | 165 | 25 | 13.89 |
| | | 165 | 170 | 68 | 0.20 |
| | | 170 | 175 | 49 | 3.47 |
| | | 175 | 180 | 73 | 5.14 |
| | | 180 | 185 | 49 | 9.96 |
| | | 185 | 190 | 106 | 2.89 |
| | | 190 | 195 | 43 | 4.24 |
| | maximum stream width | 2.5 | 5.0 | 65 | 6.34 |
| | | 5.0 | 7.5 | 84 | 3.62 |
| | | 7.5 | 10.0 | 60 | 4.34 |
| | | 10.0 | 12.5 | 57 | 6.12 |
| | | 12.5 | 15.0 | 22 | 15.77 |
| | | 15.0 | 17.5 | 33 | 3.24 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | maximum stream width | 17.5 | 20.0 | 15 | 2.97 |
| | | 20.0 | 22.5 | 8 | 1.44 |
| | | 22.5 | 25.0 | 9 | 0.79 |
| | | 25.0 | 27.5 | 5 | 1.61 |
| | | 30.0 | 32.5 | 7 | 0.48 |
| | | 35.0 | 37.5 | 5 | 0.31 |
| | | 42.5 | 45.0 | 1 | 6.61 |
| | | 45.0 | 47.5 | 2 | 4.87 |
| | | 52.5 | 55.0 | 1 | 0.78 |
| | | 125.0 | 127.5 | 1 | 0.11 |
| | mean depth | 0.0 | 0.5 | 254 | 2.78 |
| | | 0.5 | 1.0 | 135 | 6.50 |
| | | 1.0 | 1.5 | 23 | 12.74 |
| | | 1.5 | 2.0 | 5 | 0.98 |
| | | 2.0 | 2.5 | 1 | 0.56 |
| | mean width | 0.0 | 2.5 | 39 | 4.14 |
| | | 2.5 | 5.0 | 102 | 5.09 |
| | | 5.0 | 7.5 | 92 | 3.48 |
| | | 7.5 | 10.0 | 70 | 7.49 |
| | | 10.0 | 12.5 | 38 | 6.53 |
| | | 12.5 | 15.0 | 18 | 1.84 |
| | | 15.0 | 17.5 | 22 | 1.65 |
| | | 17.5 | 20.0 | 7 | 2.01 |
| | | 20.0 | 22.5 | 6 | 0.39 |
| | | 22.5 | 25.0 | 5 | 2.64 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | mean width | 27.5 | 30.0 | 2 | 3.30 |
| | | 30.0 | 32.5 | 5 | 0.29 |
| | | 37.5 | 40.0 | 1 | 0.67 |
| | | 45.0 | 47.5 | 2 | 0.05 |
| | | 52.5 | 55.0 | 1 | 0.78 |
| | | 110.0 | 112.5 | 1 | 0.11 |
| | minimum stream width | 0.0 | 2.5 | 106 | 7.46 |
| | | 2.5 | 5.0 | 135 | 3.82 |
| | | 5.0 | 7.5 | 69 | 6.06 |
| | | 7.5 | 10.0 | 37 | 2.46 |
| | | 10.0 | 12.5 | 23 | 1.29 |
| | | 12.5 | 15.0 | 6 | 2.76 |
| | | 17.5 | 20.0 | 8 | 1.24 |
| | | 25.0 | 27.5 | 1 | 0.44 |
| | | 52.5 | 55.0 | 2 | 0.39 |
| | | 100.0 | 102.5 | 1 | 0.11 |
| | nitrates | 0 | 5 | 91 | 3.70 |
| | | 5 | 10 | 248 | 5.67 |
| | | 10 | 15 | 23 | 3.43 |
| | | 15 | 20 | 7 | 0.11 |
| | | 20 | 25 | 5 | 0.35 |
| | | 25 | 30 | 3 | 0.03 |
| | | 35 | 40 | 3 | 2.20 |
| | | 65 | 70 | 1 | 33.51 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | pH | 6.0 | 6.5 | 1 | 0.78 |
| | | 6.5 | 7.0 | 10 | 1.15 |
| | | 7.0 | 7.5 | 38 | 10.05 |
| | | 7.5 | 8.0 | 114 | 4.81 |
| | | 8.0 | 8.5 | 149 | 3.55 |
| | | 8.5 | 9.0 | 72 | 4.85 |
| | | 9.0 | 9.5 | 14 | 3.66 |
| | pool | 0 | 10 | 152 | 1.83 |
| | | 10 | 20 | 12 | 5.15 |
| | | 20 | 30 | 19 | 2.91 |
| | | 30 | 40 | 28 | 1.43 |
| | | 40 | 50 | 22 | 3.05 |
| | | 50 | 60 | 25 | 5.16 |
| | | 60 | 70 | 21 | 3.26 |
| | | 70 | 80 | 11 | 4.77 |
| | | 80 | 90 | 26 | 11.72 |
| | | 90 | 100 | 13 | 11.65 |
| | | 100 | - | 80 | 8.42 |
| | riffle | 0 | 5 | 157 | 4.33 |
| | | 5 | 10 | 20 | 5.62 |
| | | 10 | 15 | 25 | 14.55 |
| | | 15 | 20 | 30 | 1.36 |
| | | 20 | 25 | 15 | 1.88 |
| | | 25 | 30 | 17 | 1.36 |
| | | 30 | 35 | 12 | 7.27 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | riffle | 35 | 40 | 8 | 0.21 |
| | | 40 | 45 | 6 | 1.08 |
| | | 50 | 55 | 4 | 7.20 |
| | | 55 | 60 | 3 | 3.51 |
| | | 60 | 65 | 3 | 4.55 |
| | | 75 | 80 | 1 | 0.44 |
| | | 85 | 90 | 1 | 19.39 |
| | run | 0 | 15 | 145 | 8.22 |
| | | 15 | 30 | 20 | 3.61 |
| | | 30 | 45 | 42 | 3.27 |
| | | 45 | 60 | 26 | 5.37 |
| | | 60 | 75 | 23 | 0.93 |
| | | 75 | 90 | 18 | 2.75 |
| | | 90 | 100 | 134 | 1.73 |
| | total alkalinity | 0 | 30 | 1 | 0.89 |
| | | 30 | 60 | 1 | 3.06 |
| | | 60 | 90 | 1 | 0.11 |
| | | 90 | 120 | 7 | 5.78 |
| | | 120 | 150 | 11 | 5.44 |
| | | 150 | 180 | 19 | 7.26 |
| | | 180 | 210 | 21 | 6.35 |
| | | 210 | 240 | 37 | 11.60 |
| | | 240 | 270 | 30 | 18.44 |
| | | 270 | 300 | 11 | 25.92 |
| | | 300 | 330 | 6 | 38.81 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | total alkalinity | 330 | 360 | 3 | 8.29 |
| | | 360 | 390 | 2 | 6.05 |
| | | 390 | 420 | 1 | 1.00 |
| | | 420 | 450 | 1 | 23.31 |
| | | 450 | 480 | 1 | 0.11 |
| | total dissolved solids | 0 | 200 | 56 | 2.58 |
| | | 200 | 400 | 69 | 1.96 |
| | | 400 | 600 | 38 | 1.19 |
| | | 600 | 800 | 11 | 2.17 |
| | | 800 | 1000 | 12 | 0.83 |
| | | 1000 | 1200 | 5 | 0.22 |
| | | 1200 | 1400 | 8 | 0.26 |
| | | 1600 | 1800 | 4 | 10.03 |
| | | 1800 | 2000 | 2 | 4.98 |
| | | 3400 | 3600 | 1 | 23.20 |
| | total phosphates | 0.0 | 0.3 | 193 | 6.14 |
| | | 0.3 | 0.6 | 86 | 4.13 |
| | | 0.6 | 0.9 | 48 | 1.53 |
| | | 0.9 | 1.2 | 19 | 3.02 |
| | | 1.2 | 1.5 | 13 | 1.10 |
| | | 1.5 | 1.8 | 8 | 17.27 |
| | | 1.8 | 2.1 | 3 | 0.26 |
| | | 2.4 | 2.7 | 3 | 0.33 |
| | | 2.7 | 3.0 | 3 | 3.02 |
| | | 3.0 | 3.3 | 1 | 23.31 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | total phosphates | 3.3 | 3.6 | 6 | 1.99 |
| | | 4.5 | 4.8 | 1 | 2.46 |
| | | 6.0 | 6.3 | 1 | 0.11 |
| | turbidity | 0 | 15 | 90 | 5.80 |
| | | 15 | 30 | 71 | 6.35 |
| | | 30 | 45 | 34 | 1.24 |
| | | 45 | 60 | 15 | 2.48 |
| | | 60 | 75 | 15 | 0.91 |
| | | 75 | 90 | 3 | 1.12 |
| | | 90 | 105 | 4 | 38.64 |
| | | 120 | 135 | 4 | 1.73 |
| | | 270 | 285 | 2 | 9.69 |
| | | 450 | 465 | 2 | 0.11 |
| | | 510 | 525 | 1 | 0.11 |
| | velocity | 0.00 | 0.25 | 291 | 5.69 |
| | | 0.25 | 0.50 | 53 | 1.78 |
| | | 0.50 | 0.75 | 14 | 0.51 |
| | | 0.75 | 1.00 | 9 | 0.22 |
| | | 1.00 | 1.25 | 4 | 0.81 |
| | | 1.50 | 1.75 | 1 | 9.97 |
| | | 5.75 | 6.00 | 1 | 2.24 |
| | water temperature | 0 | 4 | 3 | 2.95 |
| | | 4 | 8 | 16 | 0.05 |
| | | 8 | 12 | 41 | 0.56 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | water temperature | 12 | 16 | 27 | 8.48 |
| | | 16 | 20 | 45 | 4.84 |
| | | 20 | 24 | 98 | 3.83 |
| | | 24 | 28 | 129 | 6.51 |
| | | 28 | 32 | 41 | 2.09 |
| | | 32 | 36 | 3 | 0.03 |
| | | 36 | 40 | 1 | 0.11 |
| White Crappie | conductivity | 0 | 300 | 10 | 1.30 |
| | | 300 | 600 | 71 | 2.31 |
| | | 600 | 900 | 48 | 0.62 |
| | | 900 | 1200 | 35 | 0.24 |
| | | 1200 | 1500 | 13 | 0.04 |
| | | 1500 | 1800 | 5 | 8.67 |
| | | 2700 | 3000 | 5 | 10.37 |
| | dissolved oxygen | 3 | 4 | 1 | 0.56 |
| | | 4 | 5 | 7 | 0.81 |
| | | 5 | 6 | 14 | 6.02 |
| | | 6 | 7 | 25 | 1.47 |
| | | 7 | 8 | 47 | 0.46 |
| | | 8 | 9 | 1 | 1.50 |
| | | 9 | 10 | 45 | 1.64 |
| | | 10 | 11 | 48 | 0.97 |
| | | 11 | 12 | 38 | 0.84 |
| | | 12 | 13 | 38 | 2.77 |
| | | 13 | 14 | 18 | 0.25 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | conductivity | 0 | 300 | 10 | 1.30 |
| | | 300 | 600 | 71 | 2.31 |
| | | 600 | 900 | 48 | 0.62 |
| | | 900 | 1200 | 35 | 0.24 |
| | | 1200 | 1500 | 13 | 0.04 |
| | | 1500 | 1800 | 5 | 8.67 |
| | | 2700 | 3000 | 5 | 10.37 |
| | dissolved oxygen | 3 | 4 | 1 | 0.56 |
| | | 4 | 5 | 7 | 0.81 |
| | | 5 | 6 | 14 | 6.02 |
| | | 6 | 7 | 25 | 1.47 |
| | | 7 | 8 | 47 | 0.46 |
| | | 8 | 9 | 1 | 1.50 |
| | | 9 | 10 | 45 | 1.64 |
| | | 10 | 11 | 48 | 0.97 |
| | | 11 | 12 | 38 | 0.84 |
| | | 12 | 13 | 38 | 2.77 |
| | | 13 | 14 | 18 | 0.25 |
| | | 14 | 15 | 19 | 0.23 |
| | | 16 | 17 | 8 | 2.14 |
| | gradient | 0.0 | 0.5 | 54 | 0.60 |
| | | 0.5 | 1.0 | 98 | 5.69 |
| | | 1.0 | 1.5 | 88 | 1.37 |
| | | 1.5 | 2.0 | 41 | 0.41 |
| | | 2.0 | 2.5 | 27 | 0.81 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | gradient | 2.0 | 3.0 | 22 | 1.34 |
| | | 4.0 | 4.5 | 4 | 0.02 |
| | | 4.5 | 5.0 | 2 | 13.78 |
| | | 5.0 | 5.5 | 6 | 2.48 |
| | growing season (frost-free days) | 80 | 85 | 1 | 2.91 |
| | | 165 | 170 | 68 | 0.03 |
| | | 170 | 175 | 49 | 0.03 |
| | | 175 | 180 | 73 | 0.81 |
| | | 180 | 185 | 49 | 2.34 |
| | | 185 | 190 | 106 | 5.16 |
| | | 190 | 195 | 43 | 2.28 |
| | magnesium hardness | 0 | 100 | 264 | 1.20 |
| | | 100 | 200 | 71 | 0.92 |
| | | 200 | 300 | 19 | 6.05 |
| | | 300 | 400 | 5 | 0.26 |
| | maximum stream width | 2.5 | 5.0 | 65 | 0.72 |
| | | 5.0 | 7.5 | 84 | 0.71 |
| | | 7.5 | 10.0 | 60 | 0.46 |
| | | 10.0 | 12.5 | 57 | 1.79 |
| | | 12.5 | 15.0 | 22 | 3.12 |
| | | 15.0 | 17.5 | 33 | 11.01 |
| | | 17.5 | 20.0 | 15 | 6.00 |
| | | 20.0 | 22.5 | 8 | 3.83 |
| | | 22.5 | 25.0 | 9 | 0.62 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | maximum stream width | 27.5 | 30.0 | 2 | 0.84 |
| | | 30.0 | 32.5 | 7 | 0.59 |
| | | 35.0 | 37.5 | 5 | 0.60 |
| | | 37.5 | 40.0 | 4 | 0.22 |
| | | 45.0 | 47.5 | 2 | 1.34 |
| | | 52.5 | 55.0 | 1 | 0.11 |
| | mean depth | 0.00 | 0.25 | 112 | 0.34 |
| | | 0.25 | 0.50 | 142 | 1.76 |
| | | 0.50 | 0.75 | 83 | 1.01 |
| | | 0.75 | 1.00 | 52 | 1.57 |
| | | 1.00 | 1.25 | 20 | 17.86 |
| | | 1.25 | 1.50 | 3 | 0.78 |
| | | 1.50 | 1.75 | 5 | 2.15 |
| | | 2.00 | 2.25 | 1 | 1.12 |
| | mean width | 0.0 | 2.5 | 39 | 0.38 |
| | | 2.5 | 3.0 | 102 | 0.38 |
| | | 5.0 | 7.5 | 92 | 3.76 |
| | | 7.5 | 10.0 | 90 | 3.01 |
| | | 10.0 | 12.5 | 38 | 0.67 |
| | | 12.5 | 15.0 | 18 | 4.95 |
| | | 15.0 | 17.5 | 22 | 3.04 |
| | | 17.5 | 20.0 | 7 | 1.39 |
| | | 20.0 | 22.5 | 6 | 2.65 |
| | | 22.5 | 25.0 | 5 | 0.17 |
| | | 27.5 | 30.0 | 2 | 1.17 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | mean width | 30.0 | 32.5 | 5 | 0.78 |
| | | 45.0 | 47.5 | 2 | 0.33 |
| | | 52.5 | 55.0 | 1 | 0.11 |
| | nitrates | 0 | 5 | 91 | 1.21 |
| | | 5 | 10 | 248 | 1.31 |
| | | 10 | 15 | 23 | 3.16 |
| | | 15 | 20 | 7 | 1.95 |
| | | 20 | 25 | 5 | 0.13 |
| | pH | 4.0 | 4.5 | 1 | 0.78 |
| | | 6.5 | 7.0 | 10 | 0.08 |
| | | 7.0 | 7.5 | 39 | 1.64 |
| | | 7.5 | 8.0 | 114 | 1.42 |
| | | 8.0 | 8.5 | 149 | 1.12 |
| | | 8.5 | 9.0 | 72 | 1.75 |
| | | 9.0 | 9.5 | 14 | 1.53 |
| | riffle | 0 | 5 | 257 | 2.10 |
| | | 5 | 10 | 20 | 5.02 |
| | | 10 | 15 | 25 | 2.86 |
| | | 15 | 20 | 30 | 0.81 |
| | | 20 | 25 | 15 | 0.62 |
| | | 25 | 30 | 17 | 0.16 |
| | | 30 | 35 | 12 | 1.40 |
| | | 35 | 40 | 8 | 1.30 |
| | | 50 | 55 | 4 | 10.42 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | riffle | 55 | 60 | 3 | 0.11 |
| | | 60 | 65 | 3 | 0.56 |
| | | 85 | 90 | 1 | 7.06 |
| | total phosphates | 0.0 | 0.6 | 279 | 1.10 |
| | | 0.6 | 1.2 | 67 | 0.97 |
| | | 1.2 | 1.8 | 21 | 3.96 |
| | | 1.8 | 2.4 | 8 | 2.64 |
| | | 2.4 | 3.0 | 6 | 4.55 |
| | turbidity | 0 | 25 | 144 | 2.38 |
| | | 25 | 50 | 58 | 1.76 |
| | | 50 | 75 | 23 | 0.70 |
| | | 100 | 125 | 8 | 0.02 |
| | | 275 | 300 | 2 | 3.53 |
| | | 400 | 475 | 2 | 3.30 |
| | velocity | 0.0 | 0.5 | 344 | 2.13 |
| | | 0.5 | 1.0 | 23 | 1.37 |
| | | 1.0 | 1.5 | 6 | 0.20 |
| | | 5.5 | 6.0 | 1 | 1.34 |
| | volume of flow | 0 | 3 | 357 | 2.06 |
| | | 3 | 6 | 7 | 4.37 |
| | | 6 | 9 | 6 | 0.05 |
| | | 24 | 27 | 1 | 1.34 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | water temperature | 10 | 15 | 45 | 0.08 |
| | | 15 | 20 | 50 | 0.39 |
| | | 20 | 25 | 142 | 1.38 |
| | | 25 | 30 | 118 | 2.34 |
| | | 30 | 35 | 11 | 0.21 |
| Green sunfish | magnesium hardness | 0 | 200 | 335 | 17.95 |
| | | 200 | 400 | 24 | 29.53 |
| | | 400 | 600 | 9 | 9.45 |
| | | 600 | 800 | 1 | 76.89 |
| | | 800 | 1000 | 1 | 371.56 |
| | | 2400 | 2600 | 1 | 11.99 |
| | maximum stream width | 0 | 5 | 84 | 39.47 |
| | | 5 | 10 | 144 | 17.20 |
| | | 10 | 15 | 79 | 16.05 |
| | | 15 | 20 | 48 | 8.41 |
| | | 20 | 25 | 17 | 6.53 |
| | | 25 | 30 | 7 | 1.92 |
| | | 30 | 35 | 8 | 0.61 |
| | | 35 | 40 | 9 | 0.44 |
| | | 45 | 50 | 2 | 2.29 |
| | mean depth | 0 | 5 | 254 | 16.34 |
| | | 5 | 10 | 135 | 23.59 |
| | | 10 | 15 | 23 | 12.92 |
| | | 15 | 20 | 5 | 9.95 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | mean depth | 20 | 25 | 1 | 0.11 |
| | | 30 | 35 | 1 | 0.11 |
| | minimum stream width | 0.0 | 2.5 | 106 | 26.82 |
| | | 2.5 | 5.0 | 135 | 21.69 |
| | | 5.0 | 7.5 | 69 | 20.39 |
| | | 7.5 | 10.0 | 37 | 6.46 |
| | | 10.0 | 12.5 | 23 | 5.75 |
| | | 12.5 | 15.0 | 6 | 1.69 |
| | | 15.0 | 17.5 | 8 | 0.51 |
| | | 17.5 | 20.0 | 8 | 4.31 |
| | | 20.0 | 22.5 | 2 | 0.72 |
| | | 25.0 | 27.5 | 1 | 1.68 |
| | | 30.0 | 32.5 | 3 | 0.11 |
| | pH | 3.5 | 4.0 | 1 | 2.01 |
| | | 4.0 | 4.5 | 1 | 3.13 |
| | | 6.0 | 6.5 | 1 | 12.10 |
| | | 6.5 | 7.0 | 10 | 9.58 |
| | | 7.0 | 7.5 | 39 | 19.17 |
| | | 7.5 | 8.0 | 114 | 29.16 |
| | | 8.0 | 8.5 | 149 | 13.33 |
| | | 8.5 | 9.0 | 72 | 12.65 |
| | | 9.0 | 9.5 | 14 | 5.28 |
| | total phosphates | 0.0 | 0.5 | 257 | 19.81 |
| | | 0.5 | 1.0 | 75 | 19.43 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | total phosphates | 1.0 | 1.5 | 27 | 16.07 |
| | | 1.5 | 2.0 | 9 | 11.24 |
| | | 2.0 | 2.5 | 8 | 8.22 |
| | | 2.5 | 3.0 | 5 | 10.76 |
| | | 3.0 | 3.5 | 6 | 31.17 |
| | | 3.5 | 4.0 | 2 | 6.22 |
| | | 4.0 | 4.5 | 3 | 9.93 |
| | | 4.5 | 5.0 | 2 | 1.40 |
| | | 6.0 | 6.5 | 1 | 77.45 |
| | turbidity | 0 | 25 | 144 | 23.97 |
| | | 25 | 50 | 58 | 12.25 |
| | | 50 | 75 | 23 | 6.15 |
| | | 75 | 100 | 7 | 36.36 |
| | | 100 | 125 | 8 | 2.76 |
| | | 125 | 150 | 2 | 0.28 |
| | | 150 | 175 | 2 | 4.42 |
| | | 275 | 300 | 2 | 12.10 |
| | | 375 | 400 | 1 | 38.22 |
| | | 450 | 475 | 2 | 0.61 |
| | | 500 | 525 | 1 | 21.51 |
| | velocity | 0.0 | 0.5 | 344 | 19.70 |
| | | 0.5 | 1.0 | 23 | 4.09 |
| | | 1.0 | 1.5 | 6 | 3.15 |
| | | 1.5 | 2.0 | 1 | 100.20 |
| | | 3.0 | 3.5 | 1 | 16.18 |

Table 22. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | velocity | 5.5 | 6.0 | 1 | 7.28 |

APPENDIX J

DATA FOR VARIABLES, BY SPECIES,

FOR WHICH SUITABILITY CURVES

WERE NOT CONSTRUCTED

Table 23. Mean standing crop values by species for increments of physical and chemical variables for parameters for which suitability curves were not drawn.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | chlorides | 0 | 100 | 297 | 1.19 |
| | | 100 | 200 | 45 | 0.81 |
| | | 200 | 300 | 15 | 0.73 |
| | | 700 | 800 | 3 | 0.93 |
| | conductivity | 0 | 300 | 10 | 0.01 |
| | | 300 | 600 | 71 | 2.69 |
| | | 600 | 900 | 48 | 0.81 |
| | | 1200 | 1500 | 13 | 0.01 |
| | | 1500 | 1800 | 5 | 10.55 |
| | | 1800 | 2100 | 13 | 0.01 |
| | | 2700 | 3000 | 5 | 0.02 |
| | | 3000 | 3300 | 4 | 0.70 |
| | | 3900 | 4200 | 3 | 1.90 |
| | dissolved oxygen | 4 | 6 | 21 | 3.76 |
| | | 6 | 8 | 72 | 1.94 |
| | | 8 | 10 | 86 | 0.99 |
| | | 10 | 12 | 86 | 0.41 |
| | | 12 | 14 | 56 | 0.82 |
| | | 14 | 16 | 28 | 0.01 |
| | | 16 | 18 | 17 | 1.00 |
| | | 18 | 20 | 11 | 1.48 |
| | gradient | 0.0 | 0.8 | 124 | 1.17 |
| | | 0.8 | 1.6 | 122 | 1.57 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | gradient | 1.6 | 2.4 | 62 | 0.91 |
| | | 2.4 | 3.2 | 28 | 1.00 |
| | | 3.2 | 4.0 | 20 | 0.43 |
| | | 4.0 | 4.8 | 6 | 2.89 |
| | growing season | 165 | 180 | 190 | 1.30 |
| | | 180 | 195 | 198 | 1.08 |
| | magnesium hardness | 0 | 200 | 335 | 0.95 |
| | | 200 | 400 | 24 | 0.32 |
| | | 400 | 600 | 9 | 0.64 |
| | | 600 | 800 | 1 | 0.11 |
| | | 2400 | 2600 | 1 | 2.80 |
| | maximum stream width | 5.0 | 7.5 | 84 | 0.08 |
| | | 7.5 | 10.0 | 60 | 1.68 |
| | | 10.0 | 12.5 | 57 | 0.61 |
| | | 12.5 | 15.0 | 22 | 1.95 |
| | | 15.0 | 17.5 | 33 | 4.10 |
| | | 17.5 | 20.0 | 15 | 0.17 |
| | | 20.0 | 22.5 | 8 | 4.95 |
| | | 22.5 | 25.0 | 9 | 0.62 |
| | | 25.0 | 27.5 | 5 | 3.25 |
| | | 27.5 | 30.0 | 2 | 0.11 |
| | | 30.0 | 32.5 | 7 | 0.62 |
| | | 35.0 | 37.5 | 5 | 1.00 |
| | | 42.5 | 45.0 | 1 | 15.13 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | maximum stream width | 45.0 | 47.5 | 2 | 8.12 |
| | mean width | 0 | 10 | 303 | 0.46 |
| | | 10 | 20 | 85 | 3.18 |
| | | 20 | 30 | 15 | 2.89 |
| | | 30 | 40 | 9 | 0.77 |
| | | 40 | 50 | 2 | 0.05 |
| | pool | 0 | 10 | 152 | 0.86 |
| | | 10 | 20 | 12 | 1.47 |
| | | 20 | 30 | 19 | 0.62 |
| | | 30 | 40 | 28 | 0.66 |
| | | 40 | 50 | 22 | 0.77 |
| | | 50 | 60 | 25 | 1.34 |
| | | 60 | 70 | 21 | 1.18 |
| | | 70 | 80 | 11 | 0.02 |
| | | 80 | 90 | 26 | 3.56 |
| | | 90 | 100 | 13 | 0.97 |
| | | 100 | 100 | 80 | 1.05 |
| | runoff | 0 | 2 | 208 | 0.22 |
| | | 2 | 4 | 112 | 2.91 |
| | | 4 | 6 | 72 | 0.75 |
| | | 6 | 8 | 12 | 1.35 |
| | | 8 | 10 | 10 | 0.77 |
| | | 10 | 12 | 6 | 1.94 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | sulfates | 0 | 100 | 192 | 1.06 |
| | | 100 | 200 | 63 | 0.91 |
| | | 200 | 300 | 88 | 0.47 |
| | | 400 | 500 | 7 | 0.01 |
| | | 500 | 600 | 2 | 14.51 |
| | | 800 | 900 | 2 | 0.39 |
| | | 900 | 1000 | 2 | 0.05 |
| | total alkalinity | 45 | 90 | 9 | 1.83 |
| | | 90 | 135 | 33 | 0.43 |
| | | 135 | 180 | 68 | 0.28 |
| | | 180 | 225 | 110 | 1.52 |
| | | 225 | 270 | 98 | 1.08 |
| | | 270 | 315 | 46 | 1.25 |
| | | 315 | 360 | 19 | 0.01 |
| | | 585 | 630 | 1 | 23.76 |
| | total phosphates | 0.00 | 0.45 | 245 | 1.52 |
| | | 0.45 | 0.90 | 82 | 0.01 |
| | | 0.90 | 1.35 | 28 | 0.21 |
| | | 1.35 | 1.80 | 12 | 0.59 |
| | | 2.70 | 3.15 | 4 | 1.56 |
| | | 3.15 | 3.60 | 6 | 0.13 |
| | velocity | 0.0 | 0.5 | 344 | 0.98 |
| | | 0.5 | 1.0 | 23 | 0.62 |
| | | 1.0 | 1.5 | 6 | 0.24 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Spotted bass | velocity | 5.5 | 6.0 | 1 | 11.32 |
| | volume of flow | 0.0 | 2.5 | 352 | 0.96 |
| | | 2.5 | 5.0 | 12 | 1.23 |
| | | 5.0 | 7.5 | 4 | 0.36 |
| | | 25.0 | 27.5 | 1 | 11.32 |
| Slenderhead darter | magnesium hardness | 0 | 50 | 5 | 1.81 |
| | | 50 | 100 | 4 | 0.28 |
| | | 100 | 150 | 3 | 0.18 |
| | | 150 | 200 | 2 | 0.44 |
| | | 200 | 250 | 2 | 0.67 |
| | | 250 | 300 | 1 | 0.33 |
| | | 350 | 400 | 1 | 0.78 |
| | | 450 | 500 | 1 | 0.22 |
| | | 700 | 750 | 1 | 0.22 |
| | velocity | 0.00 | 0.05 | 13 | 0.86 |
| | | 0.05 | 0.10 | 2 | 0.16 |
| | | 0.10 | 0.15 | 4 | 0.81 |
| | | 0.15 | 0.20 | 2 | 1.51 |
| | | 0.20 | 0.25 | 2 | 1.00 |
| | | 0.25 | 0.30 | 1 | 0.11 |
| | | 0.80 | 0.85 | 1 | 0.56 |
| | | 1.10 | 1.15 | 1 | 0.67 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Orangethroat darter | chlorides | 0 | 75 | 113 | 2.81 |
| | | 75 | 150 | 13 | 0.68 |
| | | 150 | 225 | 8 | 2.57 |
| | | 225 | 300 | 3 | 0.14 |
| | | 300 | 375 | 1 | 0.56 |
| | | 450 | 525 | 1 | 0.22 |
| | | 600 | 675 | 1 | 1.56 |
| | total dissolved solids | 0 | 200 | 27 | 1.01 |
| | | 200 | 400 | 27 | 0.89 |
| | | 400 | 600 | 7 | 0.51 |
| | | 600 | 800 | 6 | 0.78 |
| | | 800 | 1000 | 2 | 0.39 |
| | | 1000 | 1200 | 1 | 6.05 |
| | | 1200 | 1400 | 1 | 0.11 |
| | | 1600 | 1800 | 2 | 0.33 |
| Stoneroller | calcium hardness | 0 | 100 | 9 | 15.04 |
| | | 100 | 200 | 56 | 10.22 |
| | | 200 | 300 | 60 | 12.68 |
| | | 300 | 400 | 31 | 12.35 |
| | | 400 | 500 | 6 | 2.65 |
| | | 500 | 600 | 6 | 1.86 |
| | | 600 | 700 | 5 | 31.36 |
| | | 700 | 800 | 3 | 6.65 |
| | | 900 | 1000 | 2 | 20.56 |
| | | 1100 | 1200 | 1 | 12.88 |
| | | 1300 | 1400 | 1 | 0.22 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Stoneroller | growing season | 80 | 90 | 1 | 26.00 |
| | | 160 | 170 | 48 | 19.28 |
| | | 170 | 180 | 49 | 7.11 |
| | | 180 | 190 | 75 | 6.40 |
| | | 190 | 200 | 32 | 13.74 |
| | runoff | 0.0 | 1.5 | 81 | 15.88 |
| | | 1.5 | 3.0 | 54 | 6.41 |
| | | 3.0 | 4.5 | 51 | 7.64 |
| | | 6.0 | 7.5 | 8 | 10.32 |
| | | 7.5 | 9.0 | 6 | 1.79 |
| | | 9.0 | 10.5 | 5 | 20.89 |
| Channel catfish | calcium hardness | 0 | 100 | 24 | 37.65 |
| | | 100 | 200 | 126 | 20.40 |
| | | 200 | 300 | 112 | 16.45 |
| | | 300 | 400 | 70 | 38.32 |
| | | 400 | 500 | 17 | 14.35 |
| | | 500 | 100 | 9 | 2.05 |
| | | 700 | 800 | 3 | 40.12 |
| | | 1100 | 1200 | 1 | 28.35 |
| | | 1300 | 1400 | 1 | 0.56 |
| | growing season | 160 | 165 | 25 | 25.47 |
| | | 165 | 170 | 68 | 17.61 |
| | | 170 | 175 | 49 | 31.45 |
| | | 175 | 180 | 73 | 41.26 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | growing season | 180 | 185 | 49 | 21.72 |
| | | 185 | 190 | 106 | 20.85 |
| | | 190 | 195 | 43 | 22.75 |
| | magnesium hardness | 0 | 100 | 264 | 20.68 |
| | | 100 | 200 | 71 | 31.25 |
| | | 200 | 300 | 19 | 30.41 |
| | | 300 | 400 | 5 | 34.97 |
| | | 400 | 500 | 5 | 4.03 |
| | | 500 | 600 | 4 | 8.09 |
| | | 700 | 800 | 1 | 0.11 |
| | total phosphates | 0.0 | 0.3 | 193 | 27.58 |
| | | 0.3 | 0.6 | 86 | 21.41 |
| | | 0.6 | 0.9 | 48 | 27.18 |
| | | 0.9 | 1.2 | 19 | 2.38 |
| | | 1.2 | 1.5 | 13 | 12.25 |
| | | 1.5 | 1.8 | 8 | 39.87 |
| | | 1.8 | 2.1 | 3 | 0.03 |
| | | 2.1 | 2.4 | 5 | 51.33 |
| | | 2.4 | 2.7 | 3 | 2.24 |
| | | 2.7 | 3.0 | 3 | 0.03 |
| | | 3.0 | 3.3 | 1 | 385.01 |
| | | 3.3 | 3.6 | 6 | 1.86 |
| | | 3.6 | 3.9 | 1 | 5.60 |
| | | 4.5 | 4.8 | 1 | 142.79 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Channel catfish | velocity | 0.00 | 0.25 | 291 | 24.69 |
| | | 0.25 | 0.50 | 53 | 24.02 |
| | | 0.50 | 0.75 | 14 | 39.71 |
| | | 0.75 | 1.00 | 9 | 13.31 |
| | | 1.00 | 1.25 | 2 | 3.02 |
| | | 1.50 | 1.75 | 1 | 162.74 |
| | | 2.00 | 2.50 | 1 | 0.11 |
| Largemouth bass | calcium hardness | 0 | 200 | 150 | 6.08 |
| | | 200 | 400 | 182 | 3.59 |
| | | 400 | 600 | 26 | 5.59 |
| | | 600 | 800 | 9 | 6.89 |
| | | 1000 | 1200 | 1 | 0.33 |
| | | 1200 | 1400 | 1 | 0.33 |
| | magnesium hardness | 0 | 100 | 264 | 4.41 |
| | | 100 | 200 | 7 | 5.30 |
| | | 200 | 300 | 19 | 3.74 |
| | | 300 | 400 | 5 | 5.11 |
| | | 400 | 500 | 5 | 0.17 |
| | | 500 | 600 | 4 | 5.85 |
| | | 700 | 800 | 1 | 21.74 |
| | | 800 | 900 | 1 | 91.23 |
| | runoff | 0 | 2 | 208 | 3.79 |
| | | 2 | 4 | 112 | 3.01 |
| | | 4 | 6 | 72 | 9.02 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Largemouth bass | runoff | 6 | 8 | 12 | 1.96 |
| | | 8 | 10 | 10 | 4.49 |
| | | 10 | 12 | 6 | 6.59 |
| | sulfates | 0 | 75 | 169 | 6.36 |
| | | 75 | 150 | 52 | 1.40 |
| | | 150 | 225 | 71 | 3.04 |
| | | 225 | 300 | 51 | 4.68 |
| | | 300 | 375 | 15 | 0.32 |
| | | 375 | 450 | 9 | 1.56 |
| | | 450 | 525 | 2 | 0.28 |
| | | 600 | 675 | 1 | 0.11 |
| | | 750 | 825 | 3 | 2.35 |
| | | 825 | 900 | 2 | 4.25 |
| | | 900 | 975 | 2 | 10.87 |
| | | 1200 | 1275 | 1 | 0.11 |
| | volume of flow | 0 | 2 | 349 | 5.02 |
| | | 2 | 4 | 8 | 0.33 |
| | | 4 | 6 | 7 | 1.39 |
| | | 6 | 8 | 6 | 1.62 |
| | | 18 | 20 | 1 | 0.11 |
| | | 24 | 26 | 1 | 2.24 |
| White crappie | calcium hardness | 0 | 100 | 24 | 2.38 |
| | | 100 | 200 | 126 | 1.75 |
| | | 200 | 300 | 112 | 1.23 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | calcium hardness | 300 | 400 | 70 | 0.19 |
| | | 400 | 500 | 17 | 3.11 |
| | | 500 | 600 | 9 | 1.65 |
| | | 600 | 700 | 6 | 0.48 |
| | | 1300 | 1400 | 1 | 4.14 |
| | chlorides | 0 | 50 | 235 | 1.79 |
| | | 50 | 100 | 62 | 0.31 |
| | | 100 | 150 | 33 | 1.33 |
| | | 150 | 200 | 12 | 0.31 |
| | | 200 | 250 | 10 | 0.02 |
| | | 250 | 300 | 5 | 8.33 |
| | | 850 | 900 | 1 | 2.57 |
| | | 1250 | 1300 | 1 | 14.90 |
| | minimum stream width | 0 | 5 | 241 | 2.24 |
| | | 5 | 10 | 106 | 1.05 |
| | | 10 | 15 | 29 | 5.28 |
| | | 15 | 20 | 16 | 0.76 |
| | | 20 | 25 | 5 | 0.20 |
| | | 50 | 55 | 2 | 0.05 |
| | pool | 0 | 5 | 149 | 1.00 |
| | | 5 | 10 | 3 | 0.78 |
| | | 10 | 15 | 6 | 3.84 |
| | | 20 | 25 | 11 | 0.71 |
| | | 30 | 35 | 19 | 0.81 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | pool | 35 | 40 | 9 | 0.18 |
| | | 40 | 45 | 13 | 0.27 |
| | | 45 | 50 | 9 | 3.02 |
| | | 50 | 55 | 16 | 4.44 |
| | | 55 | 60 | 9 | 6.89 |
| | | 65 | 70 | 13 | 1.21 |
| | | 70 | 75 | 4 | 0.08 |
| | | 80 | 85 | 14 | 0.74 |
| | | 85 | 90 | 12 | 4.67 |
| | | 90 | 95 | 8 | 2.15 |
| | | 95 | 100 | 5 | 0.11 |
| | | 100 | 100 | 80 | 4.51 |
| | run | 0 | 25 | 171 | 2.94 |
| | | 25 | 50 | 53 | 2.30 |
| | | 50 | 75 | 44 | 0.76 |
| | | 75 | 100 | 30 | 1.86 |
| | | 100 | 100 | 30 | 1.86 |
| | runoff | 0.0 | 1.5 | 208 | 0.44 |
| | | 1.5 | 3.0 | 112 | 4.55 |
| | | 3.0 | 4.5 | 72 | 2.15 |
| | | 6.0 | 7.5 | 12 | 0.79 |
| | | 7.5 | 9.0 | 10 | 5.73 |
| | | 9.0 | 10.5 | 6 | 0.22 |
| | sulfates | 0 | 50 | 139 | 1.73 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | sulfates | 50 | 100 | 53 | 1.00 |
| | | 100 | 150 | 29 | 0.69 |
| | | 150 | 200 | 34 | 0.55 |
| | | 200 | 250 | 52 | 2.11 |
| | | 250 | 300 | 36 | 1.57 |
| | | 300 | 350 | 12 | 1.05 |
| | | 350 | 400 | 5 | 4.23 |
| | | 400 | 450 | 7 | 0.24 |
| | | 500 | 550 | 2 | 0.44 |
| | | 750 | 800 | 3 | 0.33 |
| | | 800 | 850 | 2 | 0.16 |
| | total alkalinity | 0 | 30 | 3 | 0.26 |
| | | 30 | 60 | 3 | 9.78 |
| | | 90 | 120 | 14 | 1.16 |
| | | 120 | 150 | 33 | 0.30 |
| | | 150 | 180 | 54 | 1.62 |
| | | 180 | 210 | 63 | 1.74 |
| | | 210 | 240 | 72 | 0.69 |
| | | 240 | 270 | 73 | 1.24 |
| | | 270 | 300 | 32 | 2.76 |
| | | 300 | 330 | 21 | 0.35 |
| | | 330 | 360 | 12 | 0.84 |
| | | 390 | 420 | 6 | 0.95 |
| | | 420 | 450 | 2 | 20.84 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| White crappie | total dissolved | 0 | 400 | 125 | 1.64 |
| | | 400 | 800 | 49 | 1.04 |
| | | 800 | 1200 | 17 | 0.01 |
| | | 1200 | 1600 | 9 | 5.76 |
| Green sunfish | calcium hardness | 0 | 150 | 70 | 18.02 |
| | | 150 | 300 | 192 | 21.62 |
| | | 300 | 450 | 81 | 8.06 |
| | | 450 | 600 | 15 | 54.16 |
| | | 600 | 750 | 7 | 40.12 |
| | | 900 | 1050 | 2 | 0.16 |
| | | 1050 | 1200 | 1 | 40.68 |
| | | 1350 | 1500 | 1 | 37.10 |
| | conductivity | 0 | 300 | 1 | 37.10 |
| | | 300 | 600 | 71 | 12.73 |
| | | 600 | 900 | 48 | 14.91 |
| | | 900 | 1200 | 35 | 9.69 |
| | | 1200 | 1500 | 13 | 4.91 |
| | | 1500 | 1800 | 5 | 13.40 |
| | | 1800 | 2100 | 13 | 6.25 |
| | | 2100 | 2400 | 3 | 4.03 |
| | | 2400 | 2700 | 3 | 32.09 |
| | | 2700 | 3000 | 5 | 0.42 |
| | | 3000 | 3300 | 4 | 8.82 |
| | | 3300 | 3600 | 2 | 59.57 |
| | | 3900 | 4200 | 3 | 35.19 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | conductivity | 4500 | 4800 | 1 | 14.57 |
| | | 6300 | 6600 | 1 | 20.95 |
| | | 9000 | 9300 | 1 | 0.44 |
| | dissolved oxygen | 2 | 3 | 1 | 126.09 |
| | | 3 | 4 | 1 | 6.83 |
| | | 4 | 5 | 7 | 2.40 |
| | | 5 | 6 | 17 | 7.92 |
| | | 6 | 7 | 25 | 13.56 |
| | | 7 | 8 | 47 | 13.61 |
| | | 8 | 9 | 41 | 28.41 |
| | | 9 | 10 | 45 | 8.19 |
| | | 10 | 11 | 48 | 13.75 |
| | | 11 | 12 | 38 | 20.20 |
| | | 12 | 13 | 38 | 27.35 |
| | | 13 | 14 | 18 | 8.83 |
| | | 14 | 15 | 19 | 11.52 |
| | | 15 | 16 | 9 | 15.56 |
| | | 16 | 17 | 8 | 31.20 |
| | | 17 | 18 | 9 | 14.84 |
| | | 18 | 19 | 7 | 11.56 |
| | | 19 | 20 | 4 | 39.28 |
| | gradient | 0.0 | 0.5 | 54 | 5.52 |
| | | 0.5 | 1.0 | 98 | 11.75 |
| | | 1.0 | 1.5 | 88 | 22.95 |
| | | 1.5 | 2.0 | 41 | 17.15 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | gradient | 2.0 | 2.5 | 27 | 25.57 |
| | | 2.5 | 3.0 | 22 | 16.14 |
| | | 3.0 | 3.5 | 15 | 5.43 |
| | | 3.5 | 4.0 | 11 | 26.35 |
| | | 4.0 | 4.5 | 4 | 1.90 |
| | | 4.5 | 5.0 | 2 | 6.33 |
| | | 5.0 | 5.5 | 6 | 29.25 |
| | | 7.5 | 8.0 | 1 | 3.69 |
| | growing season | 80 | 85 | 1 | 1.34 |
| | | 90 | 95 | 1 | 38.22 |
| | | 150 | 155 | 5 | 2.51 |
| | | 160 | 165 | 25 | 51.85 |
| | | 165 | 170 | 68 | 11.20 |
| | | 170 | 175 | 49 | 14.95 |
| | | 175 | 180 | 73 | 13.72 |
| | | 180 | 185 | 49 | 23.18 |
| | | 185 | 190 | 106 | 17.07 |
| | | 190 | 195 | 43 | 20.78 |
| | mean width | 0.0 | 2.5 | 39 | 36.55 |
| | | 2.5 | 5.0 | 102 | 29.58 |
| | | 5.0 | 7.5 | 92 | 16.41 |
| | | 7.5 | 10.0 | 70 | 16.39 |
| | | 10.0 | 12.5 | 38 | 7.76 |
| | | 12.5 | 15.0 | 18 | 3.61 |
| | | 15.0 | 17.5 | 22 | 7.73 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | mean width | 17.5 | 20.0 | 7 | 5.76 |
| | | 20.0 | 22.5 | 6 | 0.61 |
| | | 22.5 | 25.0 | 5 | 0.87 |
| | | 27.5 | 30.0 | 2 | 0.22 |
| | | 30.0 | 32.5 | 5 | 0.76 |
| | | 32.5 | 35.0 | 2 | 0.16 |
| | | 37.5 | 40.0 | 1 | 0.11 |
| | | 45.0 | 47.5 | 2 | 0.11 |
| | | 72.5 | 75.0 | 1 | 0.11 |
| | nitrates | 0 | 10 | 339 | 19.06 |
| | | 10 | 20 | 30 | 20.52 |
| | | 20 | 30 | 8 | 17.97 |
| | | 30 | 40 | 5 | 17.46 |
| | | 60 | 70 | 1 | 6.27 |
| | | 90 | 100 | 1 | 5.71 |
| | pool | 0 | 10 | 163 | 14.11 |
| | | 10 | 20 | 12 | 34.79 |
| | | 20 | 30 | 19 | 10.74 |
| | | 30 | 40 | 28 | 16.19 |
| | | 40 | 50 | 22 | 20.22 |
| | | 50 | 60 | 25 | 19.17 |
| | | 60 | 70 | 21 | 9.89 |
| | | 70 | 80 | 11 | 28.54 |
| | | 80 | 90 | 26 | 14.34 |
| | | 90 | 100 | 13 | 17.67 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | pool | 100 | 100 | 80 | 28.26 |
| | riffle | 0 | 15 | 314 | 19.93 |
| | | 15 | 30 | 62 | 15.32 |
| | | 30 | 45 | 26 | 9.47 |
| | | 45 | 60 | 9 | 10.16 |
| | | 60 | 75 | 5 | 19.52 |
| | | 75 | 90 | 3 | 13.33 |
| | run | 0 | 10 | 151 | 21.63 |
| | | 10 | 20 | 12 | 13.14 |
| | | 20 | 30 | 14 | 14.64 |
| | | 30 | 40 | 30 | 12.72 |
| | | 40 | 50 | 17 | 29.37 |
| | | 50 | 60 | 21 | 18.17 |
| | | 60 | 70 | 13 | 3.19 |
| | | 70 | 80 | 15 | 20.91 |
| | | 80 | 90 | 13 | 27.97 |
| | | 90 | 100 | 12 | 2.08 |
| | | 100 | 100 | 122 | 16.76 |
| | runoff | 0 | 2 | 208 | 17.94 |
| | | 2 | 4 | 112 | 19.10 |
| | | 4 | 6 | 72 | 15.71 |
| | | 6 | 8 | 12 | 26.84 |
| | | 8 | 10 | 10 | 20.14 |
| | | 10 | 12 | 6 | 26.39 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | sulfates | 0 | 100 | 191 | 21.02 |
| | | 100 | 200 | 63 | 12.86 |
| | | 200 | 300 | 88 | 22.24 |
| | | 300 | 400 | 17 | 11.16 |
| | | 400 | 500 | 7 | 10.71 |
| | | 500 | 600 | 2 | 0.67 |
| | | 600 | 700 | 2 | 11.09 |
| | | 700 | 800 | 4 | 22.50 |
| | | 800 | 900 | 2 | 19.50 |
| | | 900 | 1000 | 2 | 38.78 |
| | | 1200 | 1300 | 1 | 28.13 |
| | total alkalinity | 0 | 50 | 4 | 21.01 |
| | | 50 | 100 | 11 | 22.83 |
| | | 100 | 150 | 45 | 12.88 |
| | | 150 | 200 | 83 | 18.26 |
| | | 200 | 250 | 124 | 14.73 |
| | | 250 | 300 | 87 | 16.54 |
| | | 300 | 350 | 30 | 53.89 |
| | | 350 | 400 | 10 | 11.43 |
| | | 400 | 450 | 7 | 11.62 |
| | | 550 | 600 | 1 | 5.38 |
| | total dissolved solids | 0 | 200 | 56 | 19.50 |
| | | 200 | 400 | 69 | 13.33 |
| | | 400 | 600 | 38 | 9.07 |
| | | 600 | 800 | 11 | 6.25 |

Table 23. Continued.

| Species | Variable | Range greater than or equal to | Less than | N | Mean standing crop |
|---|---|---|---|---|---|
| Green sunfish | total dissolved solids | 800 | 1000 | 12 | 8.14 |
| | | 1000 | 1200 | 5 | 11.20 |
| | | 1200 | 1400 | 8 | 13.36 |
| | | 1400 | 1600 | 1 | 0.11 |
| | | 1600 | 1800 | 4 | 30.87 |
| | | 1800 | 2000 | 1 | 14.57 |
| | | 3400 | 3600 | 1 | 20.95 |
| | | 4200 | 4400 | 1 | 0.44 |
| | volume of flow | 0 | 2 | 349 | 19.80 |
| | | 2 | 4 | 8 | 2.54 |
| | | 4 | 6 | 7 | 7.74 |
| | | 6 | 8 | 6 | 3.51 |
| | | 8 | 10 | 1 | 0.33 |
| | | 24 | 26 | 1 | 7.28 |
| | water temperature | 0 | 5 | 3 | 26.71 |
| | | 5 | 10 | 34 | 20.37 |
| | | 10 | 15 | 45 | 33.47 |
| | | 15 | 20 | 50 | 6.81 |
| | | 20 | 25 | 142 | 17.70 |
| | | 25 | 30 | 118 | 15.40 |
| | | 30 | 35 | 11 | 1.85 |
| | | 35 | 40 | 1 | 0.22 |

APPENDIX K

REGRESSION MODELS EXPLAINING VARIATION IN STANDING CROP (kg/ha) BY SPECIES

Table 24. Regression models explaining standing crop (kg/ha) by species. All models were significant at the .05 level. Refer to Chapter III for a description of sample methods, and respective species' chapters for model discussions.

| Species | Sample Method* | Regression equation explaining standing crop based on suitability index (SI) values |
|---|---|---|
| Spotted bass | 6 | 4.30 + (-21.24 × water temperature SI) + (20.95 × mean width SI) + (13.60 × pH SI) + (-25.65 × minimum width SI) + (9.78 × nitrate SI) + (6.95 × riffle SI) |
| | D | -5.81 + (-22.6308 × turbidity SI) + (34.47 × mean depth SI) + (-25.82 × minimum width SI) + (31.10 × mean width SI) + (19.40 × pH SI) + (10.38 × riffle SI) |
| Slenderhead darter | 6 | -1.44 + (6.88 × calcium hardness SI) + (0.83 × maximum width SI) + (1.34 × riffle SI) |
| | D | -1.12 + (2.25 × maximum width SI) + (1.67 × mean depth SI) + (-50.84 × phosphate SI) + (0.84 × total alkalinity SI) + (-5.42 × water temperature SI) |
| Orangethroat darter | 8 | -0.06 + (1.83 × mean width SI) + (0.86 × minimum width SI) + (3.20 × pool SI) + (3.86 × run SI) + (-0.38 × total alkalinity SI) |
| | 6 | -11.18 + (-6.49 × dissolved oxygen SI) + (4.46 × maximum width SI) + (8.22 × magnesium hardness SI) + (28.19 × nitrates SI) + (33.02 × phosphate SI) |

Table 24. Continued.

| Species | Sample Method* | Regression equation explaining standing crop based on suitability index (SI) values |
|---|---|---|
| Orangethroat darter | 5 | -14.72 + (-25.06 × conductivity SI) + (13.16 × growing season SI) + (16.41 × nitrate SI) + (4.75 × turbidity SI) |
| | 4 | .08 + (0.15 × mean depth SI) |
| | 3 | -18.36 + (3.09 × conductivity SI) + (-12.45 × growing season SI) + (-2.67 × mean width SI) + (4.04 × magnesium hardness SI) + (165.31 × phosphate SI) + (11.50 × pool SI) + (-9.14 × riffle SI) + (4.66 × turbidity SI) |
| | 2 | -13.40 + (-2.75 × calcium hardness) + (-7.04 × pool SI) + (10.37 × sulfate SI) + (-4.47 × total alkalinity SI) + (20.64 × water temperature SI) |
| | D | -0.15 + (1.63 × run SI) + (-0.40 × gradient SI) + (-2.03 × runoff SI) + (-0.47 × pool SI) + (0.26 × conductivity SI) |
| Central stoneroller | 7 | -73.91 + (158.27 × mean width SI) + (72.01 × magnesium hardness SI) + (7.44 × pH SI) + (18.59 × run SI) + (-24.33 × sulfate SI) |
| | 6 | -32.79 + (26.90 × growing season SI) + (-26.62 × mean depth SI) + (39.23 × mean width SI) + (18.01 × pH SI) + (15.13 × phosphate SI) + (19.08 × total alkalinity SI) + (20.47 × total dissolved solids SI) + (19.93 × water temperature SI) |

Table 24. Continued.

| Species | Sample Method* | Regression equation explaining standing crop based on suitability index (SI) values |
|---|---|---|
| Central stoneroller | 5 | 19.71 + (20.23 × dissolved oxygen SI) + (34.81 × maximum width SI) + (-15.63 × minimum width SI) + (-54.64 × magnesium hardness SI) + (59.74 × nitrate SI) + (-28.60 × pool SI) |
| | 4 | 4.20 + (1.59 × pH SI) + (-13.88 × riffle SI) + (5.26 × sulfate SI) |
| | 3 | -25.07 + (-17.77 × growing season SI) + (63.54 × run SI) + (48.52 × water temperature SI) |
| | 2 | -35.29 + (-55.94 × maximum width SI) + (180.73 × mean width SI) + (41.71 × phosphate SI) |
| | D | -1.45 + (2.66 × mean depth SI) + (-9.19 × maximum width SI) + (4.00 × water temperature SI) |
| Channel catfish | 6 | -275.13 + (126.6 × maximum width SI) + (178.76 × runoff SI) + (179.90 × run SI) + (223.58 × water temperature SI) |
| | 5 | -167.90 + (-177.45 × conductivity SI) + (340.90 × minimum width SI ) + 360.61 × pool SI) |
| | 8 | -54.41 + (325.51 × dissolved oxygen SI) + (-50.77 × pH SI) + (-227.72 × growing season SI) |

Table 24. Continued.

| Species | Sample Method* | Regression equation explaining standing crop based on suitability index (SI) values |
|---|---|---|
| Channel catfish | 4 | 47.46 + (-2.06 × pH SI) + (-7.65 × pool SI) + (-42.07 × gradient SI) |
| | 3 | 1.40 + (51.07 × conductivity SI) + (-18.65 × dissolved oxygen SI) |
| | D | -4220.43 + (6268.78 × riffle SI) + (284.96 × conductivity SI) + (-178.3870 × turbidity SI) + (-455.25 × gradient SI) + (188.11 × pH SI) + (-158.52 × total dissolved solids) + (95.13 × dissolved oxygen SI) + (-186.27 × sulfate SI) + (94.41 × pool SI) + (108.94 × runoff SI) |
| Largemouth bass | 6 | -26.46 + (39.85 × mean width SI) + (46.62 × mean depth SI) |
| | 4 | -11.62 + (36.31 × pH SI) |
| | 7 | 8.70 + (15.69 × run SI) + (-10.74 × water temperature SI) |
| | 2 | -27.79 + (164.44 × conductivity SI) + (25.83 × phosphate SI) + (-148.05 × turbidity SI) |
| | 3 | 0.94 + (22.10 × growing season SI) + (-20.90 × nitrate SI) + (24.43 × pH SI) + (6.0 × turbidity SI) |

Table 24. Continued.

| Species | Sample Method* | Regression equation explaining standing crop based on suitability index (SI) values |
|---|---|---|
| Largemouth bass | D | 72.12 + (73.97 × mean depth SI) + (22.57 × total alkalinity SI) + (-37.83 × water temperature SI) + (-34.58 × dissolved oxygen SI) + (-25.86 × total dissolved solids) + (-15.15 × turbidity SI) + (20.80 × run SI) + (-33.80 × velocity SI) + (-16.97 × gradient SI) |
| White crappie | 6 | -12.34 + (9.36 × gradient SI) + (17.46 × growing season SI) + (26.40 × magnesium hardness SI) |
| | 5 | -5.60 + (34.97 × maximum width SI) |
| | 7 | 250.91 + (15.34 × nitrate SI) + 32.69 × phosphate SI) + (-265.02 × pH SI) + (7.76 × turbidity SI) |
| | 4 | 5.51 + (-20.62 × growing season SI) + (9.65 × turbidity SI) + (8.49 × run SI) |
| | 2 | -11.77 + (31.21 × mean width SI) + (5.98 × turbidity SI) |
| | D | .23 + (4.27 × mean width SI) |
| Green sunfish | 5 | 66.86 + (94.55 × maximum width SI) + (82.78 × pH SI) |
| | 4 | 189.77 + (13.97 × pH SI) + (-196.63 × phosphate SI) |

Table 24. Continued.

| Species | Sample Method* | Regression equation explaining standing crop based on suitability index (SI) values |
|---|---|---|
| Green sunfish | 2 | -9.35 + (67.87 × maximum width SI) |
| | D | none |

* All numbered sample methods refer to Kansas data set analysis, D represents the depletion estimate method and all models so described are based on the Oklahoma data set.

2

# VITA

William George Layher

Candidate for the Degree of

Doctor of Philosophy

Thesis: HABITAT SUITABILITY FOR SELECTED ADULT FISHES IN PRAIRIE STREAMS

Major Field: Zoology

Biographical:

Personal Data: Born on July 14, 1950, in Clay Center, Kansas, the son of Paul William and Verda Marie Layher; married Barbara Sue Renner, August 16, 1975. The father of one child, Kimberly Ann, born on September 17, 1979.

Education: Graduated from Wakefield Rural High School, Wakefield, Kansas, May, 1968; received the Bachelor of Science in Education degree (major field, biology; minor field, physical science) from Emporia State University, Emporia, Kansas, May, 1972; received the Master of Science degree in Environmental Biology from Emporia State University, Emporia, Kansas, December, 1976; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in July, 1983.

Professional Experience: Biological Aide with the Bureau of Sport Fisheries and Wildlife, Flint Hills National Wildlife Refuge, John Redmond Reservoir, Kansas, October through December, 1971; Fisheries Aide with the Kansas Fish and Game Commission, Pratt, Kansas, May through August, 1977; Fish and Game Biologist I with the Kansas Fish and Game Commission, Pratt, Kansas, May through August, 1978; Biology and Physiology Instructor with Circle Unified School District No. 375, Towanda, Kansas, August, 1972 through August, 1979; Teaching Assistant with the School of Biological Sciences, Department of General and Evolutionary Biology, Oklahoma State University, Stillwater, Oklahoma, August, 1979 through May, 1980; Graduate Research Assistant with the Oklahoma Cooperative Fishery Research Unit, Oklahoma State University, Stillwater, Oklahoma, June 1980 through December 1981; Aquatic Liaison Biologist (Wildlife Program Administrator) with the Kansas Fish and Game Commission, Pratt, Kansas, January, 1982 to present.

Professional Affiliations: American Fisheries Society, Kansas Academy of Science, Oklahoma Academy of Science.

Honor Society Memberships: Phi Delta Kappa; Beta Beta Beta; Phi Kappa Phi.